

AGRONOMIC MANAGEMENT AND COMPARATIVE PERFORMANCE OF SHORT DURATION
POST-RAINY SEASON PIGEONPEA IN RICE-BASED CROPPING PATTERNS

BY

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This dissertation is
dedicated to my parents,
Mr. Abu Sayid and the
late Mrs. Ayesha Khatoon

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TABLE OF CONTENTS

	PAGE
ACKNOWLEDGMENTS.....	iii
LIST OF TABLES.....	vii
LIST OF FIGURES.....	x
ABSTRACT.....	xii
CHAPTER I INTRODUCTION.....	1
Problem	3
Hypotheses.....	3
Objectives.....	5
CHAPTER II LITERATURE REVIEW.....	6
Pigeonpea.....	6
Pigeonpea as a Component in Cropping Systems.....	8
Plant Density and Spatial Arrangement of Post-Rainy Season, Short Duration Sole Pigeonpea.....	10
Intercropping of Pigeonpea.....	13
Ratooning in Pigeonpea.....	16
CHAPTER III GROWTH AND YIELD OF SHORT DURATION POST-RAINY SEASON PIGEONPEA AS AFFECTED BY DIFFERENT PLANT SPACINGS AND PLANT DENSITIES.....	21
Introduction.....	21
Materials and Methods.....	22
Results and Discussion.....	27
Conclusions.....	33
CHAPTER IV INTERCROPPING SHORT DURATION POST-RAINY SEASON PIGEONPEA WITH MUNGBEAN AND COWPEA.....	34
Introduction.....	34
Materials and Methods.....	35
Results and Discussion.....	39
Conclusions.....	50

CHAPTER V	PRODUCTIVITY AND METHODS OF RATOONING SHORT DURATION POST-RAINY SEASON PIGEONPEA.....	54
	Introduction.....	54
	Materials and Methods.....	55
	Results and Discussion.....	56
	Conclusions.....	64
CHAPTER VI	COMPARISON OF DIFFERENT CROPPING PATTERNS ON RAINFED LOWLAND AREAS OF THE PHILIPPINES.....	65
	Introduction.....	65
	Materials and Methods.....	66
	Results and Discussion.....	72
	Conclusions.....	125
CHAPTER VII	SUMMARY AND CONCLUSIONS.....	128
	Experiment 1: Growth and Yield of Short Duration Post-Rainy Season Pigeonpea as Affected by Different Plant Spacings and Densities.....	128
	Experiment 2: Intercropping Short Duration Post- Rainy Season Pigeonpea with Mungbean and Cowpea.....	129
	Experiment 3: Productivity and Methods of Ratooning Short Duration Post-Rainy Season Pigeonpea.....	130
	Experiment 4: Comparison of Different Cropping Patterns on Rainfed Lowland Areas of the Philippines.....	131
APPENDIX.....		136
LITERATURE CITED.....		137
BIOGRAPHICAL SKETCH.....		142

LIST OF TABLES

TABLE		PAGE
3-1	Physical and chemical characteristics of the soil of all the fields used for conducting experiments one to three in different seasons at IRRI, Philippines.....	23
3-2	Grain yield of short duration post-rainy season pigeonpea as affected by different row spacings, 1986 dry season, IRRI, Philippines.....	28
3-3	Canopy light interception, leaf area index, and dry phytomass at maximum vegetative growth stage of short duration post-rainy season pigeonpea as affected by different combinations of row spacings and plant densities, 1987 dry season, IRRI, Philippines.....	30
3-4	Grain yield of the main and ratoon crop of short duration post-rainy season pigeonpea as affected by different combinations of row spacings and plant densities, 1987 dry season, IRRI, Philippines.....	32
4-1	Leaf area index (LAI), canopy light interception and dry phytomass at 6 weeks after emergence of sole and different intercrop combinations of mungbean and cowpea with short duration post-rainy season pigeonpea in a simulated rainfed upland, 1986 and 1987 dry seasons, IRRI, Philippines.....	40
4-2	Grain yield of pigeonpea, mungbean, and cowpea as obtained from sole and different intercrop combinations in a simulated rainfed upland, 1986 and 1987 dry seasons, IRRI, Philippines.....	44
4-3	Relative yield (L) of main and intercrop and land equivalent ratio (LER) of different intercrop combinations of mungbean and cowpea with short duration post-rainy season pigeonpea in a simulated rainfed upland, 1986 and 1987 dry seasons, IRRI, Philippines.....	47
4-4	Fodder yield of different intercrop combinations of mungbean and cowpea with short duration post-rainy season pigeonpea in a simulated rainfed upland, 1986 and 1987 dry seasons, IRRI, Philippines.....	49

TABLE	PAGE
4-5 Gross return and total variable costs of different intercrop combinations of mungbean and cowpea with short duration post-rainy season pigeonpea in a simulated rainfed upland, 1986 and 1987 dry seasons, IRRI, Philippines.....	51
4-6 Net returns from different intercrop combinations of mungbean and cowpea with short duration post-rainy season pigeonpea in a simulated rainfed upland, 1986 and 1987 dry seasons, IRRI, Philippines.....	52
5-1 Ratooning time, plant mortality, and primary branches of short duration, post-rainy season pigeonpea as affected by different ratooning treatments, 1986 and 1987 dry seasons, IRRI, Philippines.....	57
5-2 Increase in plant height, grain yield, pods and plant ⁻¹ , and firewood yield of short duration post-rainy season pigeonpea as affected by different ratooning treatments, 1986 and 1987 dry seasons, IRRI, Philippines.....	59
5-3 Fresh fodder yield of short duration post-rainy season pigeonpea as affected by different ratooning treatments, 1986 and 1987 dry seasons, IRRI, Philippines.....	62
5-4 Dry fodder yield of short duration post-rainy season pigeonpea as affected by different ratooning treatments, 1986 and 1987 dry seasons, IRRI, Philippines.....	63
6-1 Physical and chemical characteristics of the soil of all the fields used for conducting experiment four, IRRI, Philippines.....	68
6-2 Grain yield of rice crop of farmers' and tested cropping patterns grown with farmers' and recommended practices, respectively, at different test locations, 1985 and 1986 wet seasons, IRRI, Philippines.....	81
6-3 Cultural and management practices used in rice crop of farmers' and tested cropping patterns grown with farmers' and recommended practices, respectively, at different test locations, 1985 wet season, IRRI, Philippines.....	82
6-4 Cultural and management practices used in rice crop of farmers' and tested cropping patterns grown with farmers' and recommended practices, respectively, at different test locations, 1986 wet season, IRRI, Philippines.....	85

TABLE	PAGE
6-5 Cost of test factors of rice of farmers' and tested cropping patterns grown with farmers' and recommended practices, respectively, at different test locations, IRRI, Philippines.....	87
6-6 Cost and return analysis of the rice crop of farmers' and tested cropping patterns grown with farmers' and recommended practices, respectively, at different test locations, IRRI, Philippines.....	90
6-7 Dry fodder yield of rice of farmers' and tested cropping patterns grown with farmers' and recommended practices, respectively, at different test locations, IRRI, Philippines.....	92
6-8 Grain yield of the second crop/crop combination of the farmers' and tested cropping patterns grown at different locations, 1986 and 1987 dry seasons, IRRI, Philippines..	94
6-9 Net return of the second crop/crop combination of the farmers' and tested cropping patterns grown at different locations, 1986 and 1987 dry seasons, IRRI, Philippines..	95
6-10 Analysis of variance of the gross revenue data of the 1987 dry season crops grown at different test locations, IRRI, Philippines.....	97
6-11 Dry fodder yield of the second crop/crop combination of the farmers' and tested cropping patterns grown at different locations,, 1986 and 1987 dry seasons, IRRI, Philippines.....	109
6-12 Net return of the farmers' and tested cropping patterns grown at different locations during 1986 and 1987 seasons, IRRI, Philippines.....	119
6-13 Dry fodder yield of the farmers' and tested cropping patterns grown at different locations during 1986 and 1987 seasons, IRRI, Philippines.....	121
A-1 Regression equations and the coefficients of determination of the performances of different treatments shown in Figs. 6-7 through 6-9.....	136

LIST OF FIGURES

FIGURE		PAGE
4-1	Intercropping of pigeonpea showing row arrangement.....	37
6-1	Locations for cropping pattern testing showing the average rainfall for at least 20 years.....	67
6-2	Weekly average rainfall, and maximum, minimum and average air temperature for 1985-86 and 1986-87 seasons at IRRI, Philippines.....	73
6-3	Weekly average maximum, minimum and average relative humidity (R.H.) and solar radiation (S.R.) for 1985-86 and 1986-87 seasons at IRRI, Philippines.....	74
6-4	Weekly average pan evaporation (P.E.) for 1985-86 and 1986-87 seasons and astronomically possible sunshine duration (S.S.D.) at IRRI, Philippines.....	75
6-5	Weekly average rainfall for 1985-86 and 1986-87, and maximum, minimum and average air temperature for part of 1985-86 and full of 1986-87 at BTG, Nueva Ecija, Philippines.....	77
6-6	Weekly average rainfall, and maximum, minimum, and average air temperature for 1985-86 and 1986-87 seasons at Dagupan, Philippines, for CLS and CHS.....	79
6-7	Performances of different crop/crop combinations across the test locations in terms of gross return (GR) using modified stability analysis.....	98
6-8	Performances of different crop/crop combinations across the test locations in terms of net return (NR) using modified stability analysis.....	100
6-9	Performances of different crop/crop combinations across the test locations in terms of net return (NR) considering cash expenses only during 1987 dry season using modified stability analysis.....	102
6-10	Distribution of confidence intervals, for net return (NR) of three best performing crop/crop combinations across all the test locations during 1987 dry season...	104

FIGURE	PAGE
6-11 Distribution of confidence intervals for net return (NR) considering cash expenses only of three best performing crop/crop combinations across all the test locations during 1987 dry season.....	105
6-12 Distribution of confidence intervals for net return (NR) of three best performing crop/crop combinations across two best locations (IRRI and CLS) during 1987 dry season.....	106
6-13 Distribution of confidence intervals for net return (NR) considering cash expenses only of three best performing crop/crop combinations across two best locations (IRRI and CLS) during 1987 dry season.....	108
6-14 Soil moisture content at different test locations at 0.30 m depth as determined by gravimetric method approximately at two weeks interval during 1986 and 1987 dry seasons (DS).....	111
6-15 Soil moisture content at different test locations at 0.30 m depth as determined by gravimetric method approximately at two weeks interval during 1986 and 1987 dry seasons (DS).....	113
6-16 Soil moisture content at different test locations at 0.30 m depth as determined by gravimetric method approximately at two weeks interval during 1986 and 1987 dry seasons (DS).....	116
6-17 Soil moisture content at different test locations at 0.30 m depth as determined by gravimetric method approximately at two weeks interval.....	117

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Limited information on agronomic management for successful production of short duration post-rainy season pigeonpea [Cajanus cajan (L.) Millsp.] following rainfed lowland rice (Oryza sativa L.) necessitated that four different experiments on spatial arrangement and plant density, intercropping, ratooning and cropping pattern testing involving pigeonpea be conducted in the Philippines.

In the spatial arrangement and plant density study, closer row spacing gave higher main crop grain yield. The best treatment combination was 0.30 m row spacing and 50 plants m⁻². Grain, fodder and firewood yields of the ratoon crop were not affected by spacing and density.

The intercropping experiment was conducted in upland soil. Performance of mungbean [Vigna radiata (L.) Wilczek] as an intercrop was not satisfactory. Cowpea [Vigna unguiculata (L.) Walp. subsp. unguiculata] performed better as an intercrop but suppressed pigeonpea growth. If cowpea is used in intercropping, it should be under lower

fertility and moisture situations with 20 plants m^{-2} in two rows between rows of pigeonpea 0.6 m apart.

Ratooning of pigeonpea did not cause plant mortality but it delayed flowering due to initial vegetative regrowth. It also gave lower grain yield compared to non-ratooned plants.

In the cropping pattern study, five different patterns with recommended management were compared with farmers' patterns across six locations. Recommended management in rice gave equal or higher grain yield and better overall economic profitability but lower net return per dollar transplanting and weeding costs compared to farmers' management. Transplanting in rows was not acceptable to farmers because of a high labor requirement. For dry season crops, location x treatment interaction was significant. Modified stability analysis indicated two recommendation domains. Pigeonpea intercropped with either cowpea or mungbean, and cowpea alone did well on all evaluated aspects under better environments. Pigeonpea did not do well in terms of grain in moderately poor environments but showed promise in terms of fodder and firewood yield. Farmers perceived the importance of dry season crops for grain, but insufficiency of fodder was not perceived by them as a problem.

CHAPTER I INTRODUCTION

In terms of hectarage, the rainfed lowland is one of the most important crop production areas in the Philippines and also in many other Asian countries. In this agro-climatic situation, the farmers are assured of one transplant rice crop but a second rice crop is not always certain because of limiting moisture in the soil.

The main rice crop is usually harvested at the end of the rainy season or one or two weeks earlier. During that time the surface soil still holds enough moisture to enable germination and establishment of many upland crops provided the planting operations are timely. In addition in many places before or after establishment of upland crops, one or two occasional rainfalls occur. It was observed in the past that if the crop is established in time then even without any occasional rainfall, in the lowland paddies a crop can grow reasonably well by exploiting the water stored in the soil profile or by using the water provided by a shallow water table. But the field performance varies from crop to crop depending on soil moisture availability, crop duration, plant types, rooting characters, crop water requirements, drought tolerance capacity, cultural practices applied, etc.

Among all the crops tested in the recent past in the Philippines, 60 to 70 day mungbean was found to do the best in terms of grain yield as a post-rainy season crop under residual soil moisture conditions.

Hence, the Philippines Government has recently recommended and released a few short duration mungbean cultivars for growing as a post-rainy season crop. A few farmers in some selected areas are now gradually adopting this new mungbean crop which is helping to raise food production to some extent. But in some other prospective areas farmers have not tried this crop yet. As a result, the land in those areas remains fallow during the post-rainy season.

The situation in the livestock sector is also not very good in many Asian countries. The average health of the animals is very poor. One of the major reasons is insufficient and poor quality of feed. In many Asian countries, cultivable land area is very low and there is a high human population. As a result farmers cannot spare any cultivable land exclusively for feed production since those lands are much more important to farmers for their own food production. The area of grazing land is also very negligible in many countries.

However, a continued research effort has developed the following which could be of interest under the situations stated above:

1. Selection for earliness has identified cultivars of different crops that mature much earlier than traditional cultivars.

2. Selection for dual-purpose type, meaning that the same crop provides human food as well as a reasonable quality and quantity of livestock feed, has developed new cultivars with better promise, particularly of 60 to 70 day mungbean, 70 to 80 day cowpea and 105 to 115 day pigeonpea.

3. New equipment is available now for better establishment of upland crops under zero tillage in rainfed lowlands after rice.

Problem

Low productivity of rice during the wet season and very low utilization of rainfed lowland areas during the post-rice situation using residual soil moisture causes concern for not being able to raise the total food production to the maximum potential level. None or very little information exists about the optimum combination of row-spacing, and plant density, ratooning height and ratoonability of the newly developed short duration, dual-purpose, post-rainy season pigeonpea.

Unavailability of sufficient grazing land, and also cultivable land to be used exclusively for feed production during the time when the land is used for food or other cash crop production, causes very little feed production. As a result, the livestock sector is not improving thereby causing much concern for an insufficient draft power supply to the agro-based farm and also insufficient food of livestock origin for human health.

Hypotheses

1. If better rice cultivars and/or better management practices than farmers' were to be used, then rice productivity will improve.
2. Determination of optimum row-spacing and plant density of short duration post-rainy season pigeonpea will increase the productivity of the sole crop to a maximum possible level.

3. If it be possible to develop a suitable intercrop combination of the dual-purpose mungbean and cowpea with the short duration pigeonpea, it will enable farmers to have a staggered and increased supply of food and also livestock feed from the same field at the same time.

4. Determination of the best ratooning height and ratoonability under post-rainy moisture stress will further increase the productivity of the pigeonpea crop.

5. Testing of mungbean, cowpea and pigeonpea as sole crops, and the mungbean and cowpea in the best intercrop combinations with pigeonpea compared to farmers' fallow or mungbean in farmers' fields at different location in an after rice situation will indicate the suitability of different cropping patterns under varied agro-ecological environments. This would enable better selection of a cropping pattern for any test environment or other environments similar to those test locations.

It is assumed that if a suitable cropping pattern consisting of a dual-purpose crop in sole or in an intercrop combination can be determined which would be technically feasible, economically profitable and suitable to farmers according to their resource base and likings, then a substantial increase in both food and feed supply will occur.

Objectives

The objectives of this study were:

1. To determine the ways to improve the productivity of farmers' rainfed lowland rice.
2. To determine the optimum plant spacings and population density of short duration post-rainy season sole pigeonpea.
3. To determine the best intercrop combination of cowpea and mungbean with pigeonpea.
4. To explore the potential of pigeonpea as a dual-purpose crop compared to mungbean and cowpea.
5. To determine the methods and productivity of ratooning short duration post-rainy season pigeonpea.
6. To determine the best cropping pattern of dual-purpose crops for the lowland rainfed areas.

CHAPTER II LITERATURE REVIEW

Pigeonpea

Pigeonpea [Cajanus cajan (L.) Millsp.] is a legume crop, which grows well in tropical and sub-tropical environments extending between 30°N and 30°S latitude (Sharma et al., 1981a) but cannot tolerate even light frost during any stage of its growth (Faroda and Johri, 1981). As an agricultural crop of rainfed drylands, it has mainly evolved in India, where over 90% of the world hectareage is seeded. Besides India, Uganda and Kenya in Africa; the West Indies, Puerto Rico, and the Dominican Republic in the Caribbean region; and Burma in Asia are the major pigeonpea producing countries (Sharma et al., 1981a). In addition to these countries, according to Sharma et al. (1981a), pigeonpea is also receiving attention in the rainfed agriculture of 47 other countries including Philippines due to its low resource input requirement and capacity to produce relatively more than most other crops on a limited residual moisture supply. Though found in wide range of agro-ecological situations, the deep rooting and drought tolerant character of pigeonpea make it an especially useful crop in areas of low and uncertain rainfall and on the lighter soils (Willey et al., 1981).

Pigeonpea is grown in a wide variety of soils ranging from sandy to heavy clays and from pH 5.0 to 8.0. However, well drained, deep loam soils, free from excessive soluble salts and near-neutral in pH

are most suitable (Pathak, 1970). Waterlogging is detrimental to growth (Faroda and Johri, 1981).

The uses of pigeonpea are manifold. As a major food legume, pigeonpea is consumed in the Indian subcontinent mainly in the form of dhal, or dehusked splits (Kurien, 1981). Green pigeonpeas are relished both as cooked and smoked pods. Husks of pods are used as cattle feed; the green foliage as green manure and fodder; dried stalks as fuel or thatch; roots for soft coal; the whole plant as host for the lac insect, and foliage for rearing silkworms (Raju, 1981; Whiteman and Norton, 1981).

The use of pigeonpea as animal feed has been evaluated and reported by many workers in the past (Younge and Plucknett, 1963; Parbery, 1967). Krauss (1932) reported the wide-scale use of pigeonpea pastures in Hawaii in the 1920s, where over 1600 ha were grown mainly for beef fattening. Carrying capacities of good pure stands of pigeonpea varied from 1.2 to 3.7 animals ha^{-1} with average stocking rates of 2.5 $\text{ha}^{-1} \text{ year}^{-1}$. Average daily gains from 0.7 to 1.25 $\text{kg head}^{-1} \text{ day}^{-1}$ were recorded. Norman et al. (1980) evaluated pigeonpea as an annual legume forage and concluded that pigeonpea could make a contribution to dairy forage. Akinola et al. (1975a) and Henke et al. (1940) observed that pure stands of pigeonpea with adequate leaf and pod material are able to support high live weight gains up to 0.8 $\text{kg head}^{-1} \text{ day}^{-1}$. Gooding (1962) worked on pigeonpea sown with grass pastures and reported the use of pigeonpea as valuable dry season supplement.

By evaluating the pigeonpea harvest residues, Whiteman and Norton (1981) reported that pigeonpea pods alone had low nutritive value but could be fed with a good quality grass hay. According to them, harvest trash that contained leaf, stem, and pod also had low intake and digestibility values. They, however, concluded that further research is required to define intake, digestibility and animal production on pigeonpea forage.

Bahar and Prine (1982) reported that pigeonpea may not be an ideal forage plant because of its apparent low digestibility, especially of stems. But they concluded that considering the high protein content, pigeonpea is potentially useful as a browse crop, where mostly leaves, flowers, and pods are eaten to supplement livestock grazing on low protein perennial grass pastures.

Pigeonpea as Component in Cropping Systems

Traditionally, pigeonpea has been a long duration rainy season crop particularly in India and in most other countries where it is grown. The crop is generally grown mixed or intercropped with many different crops or as sole crop with or without ratooning on marginal and sub-marginal lands (Sharma et al., 1981c; Willey et al., 1981). As sole crop, pigeonpea had some limitations because of its long duration, low juvenile growth rate (Brakke and Gardner, 1987) and low harvest index (Willey et al., 1981). But development of early and extra early cultivars has opened new opportunities for pigeonpea cultivation (Faroda and Johri, 1981; Chauhan et al., 1984). In 1979, Narayanan and Sheldrake reported that pigeonpea has a potential as

post-rainy season crop. According to Narayanan et al. (1981), in rice fields in the post-rainy season, where irrigation is not possible, pigeonpea can be grown successfully with a minimum of fertilizer and cultural operations. Of 13 crops planted following cereals to grow on residual moisture, pigeonpea yielded the highest (2.5 mg ha^{-1}). In standing rice, 15 days earlier planting of pigeonpea gave significantly higher grain yields than planting immediately after the rice harvest. They further added that pigeonpea may also be grown as a post-rainy season crop after rainy season fallow. Sessaiah et al. (1984) tried medium duration pigeonpea as post-rainy season crop without irrigation compared to other pulse crops in India. The seeds were broadcasted at the end of November on standing paddy crop three to four days prior to paddy harvest. No preparatory cultivation, interculture or weeding was done. The crop survived on the residual moisture and fertility and gave a very low yield due to poor pod set. So, they concluded that medium maturity pigeonpea can be successfully introduced into rice fallows if sown before 15 November.

Sheldrake (1984) reported that the growing of short duration pigeonpeas in the cool post-rainy season has recently received attention in India, Australia and West Indies. According to him, under the short day conditions of cool post-rainy season, the reduced duration and growth of the plants enables them to be grown at high plant densities and to be managed more like ordinary annual crop than is possible with the tall woody shrubs produced by planting around the time of the longest day. Sheldrake (1984) further reported that a perennial extension of this system was being explored at the

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India during 1984 in which pigeonpea grown at high population density in the post-rainy season were harvested by ratooning and left in the field to give another crop of pods at the end of the rainy season. Shelldrake (1984) concluded that this system could be of advantage in large areas of peninsular India with heavy black soils, which are often left fallow during the monsoon season, largely because of the uncertainty of the monsoon and difficulty of working the land when it is wet.

Plant Density and Spatial Arrangement of Post-Rainy Season,
Short Duration Sole Pigeonpea

The International Crops Research Institute for the Semi-Arid Tropics (1978) reported that during post-rainy season, short day period and low temperature during the early period of crop growth limits the per plant productivity but with increased population density, yields were as high as, or even higher than, the rainy season crop. Row spacing of 0.25 m with plants spaced at 0.2 m (20 plants m^{-2}) was reported as optimum for rabi (winter) season pigeonpea by Sharma et al. (1978b).

Narayanan and Shelldrake (1979) commented that density of a post-rainy season crop needs to be considerably higher than that for the rainy season. They worked with different cultivars and spacing combinations for two years and reported that there were no cultivar x spacing interaction. In 1975-76 study, they obtained a significantly higher yield at 22 plants m^{-2} (0.30 x 0.15 m spacing) than at 13 plants m^{-2} (0.37 x 0.2 m spacing), whereas in the 1976-77 study,

greater yield and harvest indices were obtained at the lower plant densities of 12.5 and 25 m^{-2} , i.e., 0.57 x 0.14 m and 0.40 x 0.10 m spacings, respectively, compared to higher densities of 50 and 100 plants m^{-2} , i.e., 0.28 x 0.7 m and 0.20 x 0.5 m spacings, respectively.

Rao et al. (1980) reporting the result of 1979-80 trial, stated that in previous years, post-rainy season pigeonpeas has given significantly higher yields at a density of 50 plants m^{-2} than at 13 m^{-2} . For 1979-80 data, they reported the same trend with one cultivar but not with the other, both of which were however not statistically significant because of high variability between replicates. They used only four treatment combinations giving 12.5, 25, 50 and 100 plants m^{-2} in 1979-80 study.

Sharma et al. (1981c) reported that as post-rainy season crop, pigeonpea sowing at 0.15 x 0.15 m (45.5 plants m^{-2}) was the best density.

Hughes et al. (1981) reported that as stand density increased from 20 to 60 plants m^{-2} under rainfed conditions, maximum leaf area index increased from about two to about three. According to them, over the growing season, increasing stand density from 20 to 60 plants m^{-2} increased fractional daily average solar radiation interception by about 15%. They found an increasing relationship between the proportion of incident radiation intercepted during the growing season and pigeonpea yield.

Hughes et al. (1981) also reported that as stand density increased from 20 to 60 plants m^{-2} , the time taken to reach leaf area

index equal to one was reduced and there was an increase in maximum leaf area index. They further added that absence of supplemental irrigation did not significantly reduce early canopy development even at high plant density.

Keatinge and Hughes (1981) reported that in dry seasons in Trinidad, increase in stand density from 20 to 60 plants m^{-2} resulted in seed yields increasing up to 1.5 Mg ha^{-1} . According to them, within this range the highest densities used did not significantly accentuate moisture stress effects.

In relation to plant density, Gowda and Kaul (1982) noted that in Bangladesh during post-rainy season highest yields were obtained with a plant density of 59 plants m^{-2} as against the rainy season density of 14 m^{-2} . In another study in the same country but in different place the highest yields were obtained with plant density of 50 to 65 m^{-2} during post-rainy season.

Venkataratnam et al. (1984) in their plant density study, made a generalization that the best plant density for post-rainy season pigeonpea sowings under unirrigated conditions was around 25 plants m^{-2} .

By varying plant density within the row, 5 plant densities (10, 20, 40, 60, and 80 plants m^{-2}) were compared in 0.30 m rows of post-rainy season pigeonpea [The International Rice Research Institute (IRRI), 1984]. The highest main crop yield was from 40 plants m^{-2} . The crop was also ratooned and the combined main crop and ratoon yield was also highest at this density. It was further observed that soil water was probably a yield limiting factor at higher plant densities.

Srivastava (1984) studied the effect of row spacing and sowing dates on post-rainy season pigeonpea and reported that out of three cultivars tested, two gave higher yields at 0.25 x 0.20 m spacing compared to 0.37 x 0.13 m while the other one gave higher yield at 0.37 x 0.13 m spacing.

Intercropping of Pigeonpea

Pigeonpea is very commonly intercropped with one or more of a wide range of other crops. According to Aiyer (1949), an estimated 80 to 90% of the pigeonpea crop in India is intercropped. The most common intercropping crops are sorghum [Sorghum bicolor (L.) Moench], maize (Zea mays L.), millet [Pennisetum glaucum (L.) R. Br.], rainfed rice (Oryza sativa L.), groundnut (Arachis hypogaea L.) cowpea [Vigna unguiculata (L.) Walp. subsp. unguiculata], mungbean Vigna radiata (L.) Wilczek], and urdbean [Vigna mungo (L.) Hepper]. In Africa, pigeonpea is commonly intercropped with cereals, pulses and root crops (Acland, 1971). In Central and South America and the Caribbean countries, the most common intercrop is maize (Ariyanayagam, 1975; Dalal, 1974). In this review, intercropping of pigeonpea in general with legumes and more particularly with cowpea and mungbean will be discussed.

Willey et al. (1981) in describing the different intercropping systems, stated that the most common legume intercrop in Africa is cowpea, but no experimental reports on this association have been issued so far. In India, the most common legume intercrop is groundnut, while cowpea and mungbean also occur frequently.

In a study on intercropping of pigeonpea with other crops, Sen et al. (1966) reported that intercropping provided insurance against natural hazards. They further added that mixed cropping with rainfed paddy was profitable, but losses incurred when groundnut and mungbean were grown in association with pigeonpea.

Singh et al. (1979) reported that growing short duration blackgram [Vigna mungo (L.) Hepper.] and greengram [Vigna radiata (L.) Wilczek] as intercrop between rows of rainfed pigeonpea normally spaced 0.60 m apart was profitable. But intercropping with cowpea was non-profitable.

In 1979, Saxena and Yadav reported that two rows of blackgram, greengram and cowpea could be successfully grown between the normally spaced (0.75 x 0.25 m) pigeonpea without affecting its yield.

Successful intercropping of pigeonpea with mungbean was also reported by Giri and De (1978), Singh and Singh (1980), Giri et al. (1981), Sharma et al. (1981b), Yadav and Yadav (1981), and Singh et al. (1981b). Sharma et al. (1981b), however, reported that intercropping of pigeonpea with cowpea was not better than sole crop of pigeonpea in terms of total production and net income. As a reason they mentioned that due to early growth of cowpea, it was found to depress both the growth and yield of the main crop of pigeonpea.

In another study on intercropping pigeonpea with mungbean, cowpea and peanut (Arachis hypogaea L.) to identify superior legume combinations for grain and fodder, IRRI (1985) reported that the most promising combination was pigeonpea and cowpea followed by pigeonpea and mungbean. Pigeonpea and peanut was the least favorable. The Land

Equivalent Ratio of pigeonpea and cowpea was 1.48 and that of pigeonpea and peanut only 0.99. The pigeonpea and cowpea combination produced the highest fresh fodder (39.9 Mg ha^{-1}) and dry fodder yields (4.6 Mg ha^{-1}).

In 1985, Patel and Bhardwaj reported that intercropping of pigeonpea with legumes adversely affected the main crop yield. But despite main crop yield reduction which varied with the intercrop, the total production per unit area (pigeonpea equivalent) was higher with intercropping treatments than from a solid stand of pigeonpea. They further added that greengram, blackgram, and groundnut appeared to be compatible intercrops with pigeonpea.

Successful intercropping depends very much on proper spatial arrangement and adjustment of the plant population of the involved crops. Little work has been reported so far on this subject, particularly involving mungbean and cowpea as intercrops in pigeonpea.

In 1979, Saxena and Yadav reported that successful production of two rows of greengram, blackgram, or cowpea between two rows of pigeonpea (0.75 m apart) was possible. But profitability of growing one row or two rows between rows of pigeonpea differed between years and among the intercrops. Production of two rows of blackgram instead of one row was, however, more profitable in both the years studied. Singh and Singh (1980) observed that one row of intercrop between rows of pigeonpea (0.6 m apart) was better and mung and blackgram were the most suitable intercrops compared to cowpea, soybean [*Glycine max* (L.) Merr.], til (*Sesamum indicum* L.), kangni (*Setaria italica* L.) and sawan (*Panicum milliaqe*). Singh et al. (1981a) worked with various

intercrops and row arrangements of both the main and intercrops and reported that paired rows (0.4–0.8 m) of pigeonpea gave better returns than single 0.6 m rows when intercropped with blackgram. All of the above work was, however, done during the rainy season and with regular field preparation.

No work has so far been reported on intercropping extra short duration post-rainy season pigeonpea with or without full tillage. But Sharma et al. (1981c) indicated in their paper that the possibility of intercropping mungbean between rows of dry season pigeonpea sown in regular (0.3 m) or paired rows (0.2–0.4 m) appeared promising.

Ratooning in Pigeonpea

Cutting the entire plant at the base and drying before threshing for seed harvest is the usual harvest procedure in pigeonpea where ratooning is not done. But for ratooning, plants are cut above the branching level for regrowth. Depending on interest, ratooning is done either for additional forage yield or seed yield, or for both. The possibility of harvesting substantial forage and a subsequent seed crop has been indicated by Killinger (1968). Harvesting of green fodder by repeated cuts has been reported by Akinola et al. (1975b) and Salih (1981). Akinola and Whiteman (1975) studied two early and two late maturing cultivars for dry matter and nitrogen yield under different "defoliation" (ratooning) treatments. They observed that eight and 12 week "defoliation" frequencies could be successfully

integrated to incorporate cattle grazing and forage and seed production into a single management system.

In 1977, ICRISAT investigated the effects of different ratooning treatments at the time of the first harvest on second harvest yield. They reported that when the plants were ratooned progressively closer to the ground, there was more regenerative vegetative growth before they again begin flowering. Non-ratooned plants were first to begin flowering again and produced a second crop of pods sooner than any of the ratooned plants. Highest second harvest seed yield came from the non-ratooned plants whereas the lowest seed yield came from the plants which were ratooned closest to the ground. In the report it was concluded that non-ratooning was the best treatment, probably because the second crop of pods was produced with minimum delay at a time when water stress was becoming progressively greater.

In 1978, ICRISAT reported that ratooning tends to increase the sensitivity of cultivars to diseases and may result in build-up of both insects and diseases. There is often a reduction in plant stand in the ratoon crop, especially where Fusarium wilt is present.

Sharma et al. (1978a) worked on yield trials of pigeonpea cultivars grouped into early (maturing in less than 160 days), medium (maturing in 160 to 200 days), and late maturing (maturing in more than 200 days) which were harvested for grain at maturity by ratooning. Cutting was done at 0.30 to 0.40 m above the lowest pod-bearing branch. Plant survival after ratooning and regrowth varied among cultivars in all tests. First harvest of early cultivars was affected by high pod borer damage, and the second grain crop was equal

to the first on average. Medium cultivars produced a second crop approximately 50 percent of the first, and late cultivars produced no grain after the first harvest. According to them, indications of cultivar differences for survival and regeneration after ratooning suggested the possibility of effective selection for these characteristics. Further research along this line was also recommended.

Venkataratnam and Sheldrake (1985) worked from 1976 to 1981 on second harvest yields of medium duration pigeonpea at ICRISAT. The pigeonpeas were sown soon after the onset of the monsoon, in June or July; first harvest of grain yields was done around December and then the plants were ratooned at different heights by hand using either shears or small sickles. The second harvest was made around March. The results indicated that plants ratooned at 0.45 or 0.3 m yielded only between half and two-thirds as much as ones ratooned at 0.9 m, and those cut back to 0.1 m gave extremely low second harvest yields. The highest second harvest yield was obtained from the plants either non-ratooned or ratooned furthest away from the ground. According to them, the yield reductions due to ratooning closer to the ground were due to both greater mortality of the plants and greater delay in the development of the second flush of pods. The nearer to the ground the plants were cut, the more vegetative regrowth took place before flowering began on the new shoots, and the later the second flush of pods matured. They further added that such delays exposed the plants to increasing water stress.

As an additional reason for lower yield from the plants ratooned closer to the ground, Venkataratnam and Sheldrake (1985), mentioned that greater amounts of stem removal might have deprived the plants from reserves of mineral nutrients and assimilates which might have been stored within the stems.

According to Venkataratnam and Sheldrake (1985), higher yields were obtained, if the first harvest is taken by pod picking, rather than ratooning; but pod-picking is more time-consuming and expensive. They added that if the plants are ratooned then the best would be to ratoon them as high as possible. They further added that in circumstances where the mature first flush of pods is not likely to be eaten by animals or stolen and where the probability of rainfall is low, it may be economically advantageous to eliminate the first harvest altogether and harvest both first and second flushes of pods together.

Tayo (1985) made an assessment of the effect of ratooning pigeonpea in Nigeria. He planted the crop on a ridge and two to three weeks after the seed was harvested by hand picking, the ratooning treatments were applied. At second maturity, grain harvests and other evaluations were done but no ratooning was done. At third maturity, i.e., at the end of second regrowth, both grain harvests and other evaluations were done again. At the end of the first and second regrowths, on a cumulative basis, the plants ratooned at 0.3 and 0.6 m performed better than those left intact in terms of growth and yield characters including seed yield. The plants ratooned at 0.3 m performed best followed by those ratooned at 0.6 m. The total seed

yield from the planting was 3 to 6 times higher than if the crop had been harvested once. Tayo (1985) hence concluded that ratooning pigeonpea leads to significantly higher seed yield than harvesting once, and cutting the main stem back to 0.3 m is the best form of ratooning under the prevailing lowland tropical conditions.

CHAPTER III
GROWTH AND YIELD OF SHORT DURATION POST-RAINY SEASON PIGEONPEA AS
AFFECTED BY DIFFERENT PLANT SPACINGS AND PLANT DENSITIES

Introduction

The short duration post-rainy season pigeonpea is different in many aspects from the traditional long duration, rainy season pigeonpea. According to The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (1978) post-rainy season characterized by short days and low temperatures during the early period of crop growth, limits the per plant productivity, but with increased plant density, yields become the same or higher than in the rainy season crop. By working with different cultivars and spacing combinations, Narayanan and Sheldrake (1979) suggested that density of a post-rainy season crop needs to be considerably higher than that of the rainy season crop. According to Rao et al. (1980) significantly higher grain yields of post-rainy season pigeonpea were obtained at a density of 50 plants m^{-2} . Sharma et al. (1981b) reported the best plant spacings and densities for post-rainy season pigeonpea as 0.15 x 0.15 m and 45.5 plants m^{-2} , respectively. Other studies that have been reported along this line includes those of Keatinge and Hughes (1981), Gowda and Kaul (1982), Srivastava (1984), and IRRI (1984). All the work reviewed so far except IRRI (1984) were on cultivars of little longer duration than the one used for the work reported in this paper. The objective of this paper was to determine the optimum

combination of plant spacing and density of short duration post-rainy season pigeonpea.

Materials and Methods

Experiment 1 was conducted in lowland following rainfed rice crop at the International Rice Research Institute (IRRI) at Los Banos, Laguna (14°13' lat. N and 121°15' long. E), Philippines, during the 1986 and 1987 dry seasons. The first year treatments included all combinations of three levels of plant density (20, 40, and 60 plants m^{-2}) and three row widths 0.45, 0.6, and 0.75 m apart. In the second year, the treatments were changed to all possible combinations of four levels of plant density (20, 30, 40, and 50 plants m^{-2}) and the three row widths, 0.3, 0.45, and 0.6 m apart. Within row spacing was adjusted according to plant density. The experimental design used was randomized complete block with three replications in both years. Individual plot size was 22.50 and 19.12 m^2 in 1986 and 1987, respectively.

The physical and chemical characteristics of the soils of both the fields under this trial and other trials are presented in Table 3-1.

Crop establishment was done by zero tillage technique. The rice stubbles and weeds were mowed first to a level of around 0.05 to 0.10 m from the ground. Then, in the first year, narrow furrows were opened with drag stick fitted behind a small hand tractor. Fertilizer at a rate of 30-25-50 kg ha^{-1} of N, P, and K, respectively, was

Table 3-1. Physical and chemical characteristics of the soil of all the fields used for conducting experiments one to three in different seasons at IRRI, Philippines.

Experiment			Field No.	Particle size			pH 1:1 w/v H ₂ O	Org. C (%)	CEC meq/ 100 g ads [†]	Total N (%)	Avail. P (Olsen) ppm ads	Exch. K meq/ 100 g ads
No.	Season	Year		Clay (%)	Silt (%)	Sand (%)						
1,3	DS [‡]	1986	N-5	44	43	13	6.5	1.01	31.4	0.098	24	1.07
1	DS	1987	E-47(A)	47	40	13	6.2	1.22	33.6	0.125	36	0.95
2	DS	1986	UN-2	48	38	14	5.5	0.93	29.0	0.106	42	1.36
2	DS	1987	UV-1	41	45	14	5.8	1.29	30.0	0.118	35	1.03
3	DS	1987	E-49(B)	42	38	20	6.4	1.36	34.3	0.129	47	1.13

[†]ads = air-dried soil.

[‡]DS = dry season.

applied in the furrows then pigeonpea seeds (cv QPL 72) were hand drilled and afterwards the furrows were covered manually. In the second year, instead of drag stick, the recently developed inverted T-seeder (Choudhary and Aban, 1986) was used which incorporated both seeding and covering. In the second year no fertilizer was applied in the lowland. In both the years and situations, seeds were treated with Brassicol (Pentachloronitro benzene technical) at a rate of 375 g 100 kg^{-1} seeds before seeding for control of fungal diseases.

Dates of crop establishment were December 27, 1985, and December 20, 1986, for first and second year, respectively.

After emergence of the seedlings, those were thinned or reseeded to stand. Final thinnings were done at the end of 3 weeks after emergence (WAE) to maintain the desired population density. Weed control in both the years was done by hand once.

Insect control was done by spraying either Monocrotophos [3-(Dimethoxyphosphinoxy)-N-methyl-cis-crotonamide] or Cypermethrin [Cyano(3-phenoxyphenyl)methyl 3-(2,2-dichloroethenyl)-2,2-dimethyl-cyclopropanecarboxylate] or Delamethrin [Cyano (3-phenoxyphenyl) methyl 3-(2,2 dibromoethenyl)-2,2-dimethyl cyclopropanecarboxylate] at a rate of 0.50, and 0.025 kg ha^{-1} , respectively, for the first and last two insecticidal applications as and when required.

At maturity, plant height was measured on 10 plants plot^{-1} and harvesting of the matured pods were done by hand picking either once or twice, depending on the needs. Pods were threshed by drying and beating the pods in cloth or jute sacks. After threshing, moisture contents of the grain samples were determined by "Steinlite Electronic

Moisture Tester" (Seedburo Equipment Co., USA). Finally, grain yield plot^{-1} was converted to Mg ha^{-1} and adjusted to 12% moisture content. Harvest area varied slightly from one treatment to the other due to differences in row spacings. But by counting and measuring the number and length of rows, respectively, as far as possible an uniform area across the treatments were harvested. The minimum harvest area was 12 and 8 m^2 for 1986 and 1987, respectively. Data on yield components (number of pods plant^{-1} , number of seeds pod^{-1} , 100 seed weight) were also recorded.

After harvesting all the matured pods, the plants were ratooned. Ratooning was done by cutting with sickles and by removing the upper 20 and 40% of the canopy in the first and second year, respectively. Cuttings were done in dome shape so that tips of all the branches were cut to allow sufficient regrowth. After ratooning, fresh and oven dry weight of the clipped off fodder was recorded and the plants were allowed to regrow until the end of the following June when it became essential to vacant the land for next rice or other crop.

During harvest of the ratooned crop, same sample area as for initial harvest was maintained in the respective treatment. If there were any matured harvestable pods, then those were harvested and threshed in the way described earlier; otherwise the whole plants in the sample area were cut at the base by sickle. The fresh weight of all the plants in the sample area was taken and recorded. To determine the dry weight of the plants of the sample area, one kilogram fresh weight of the sample was taken and oven dried. Then the derived proportion of dry weight out of one kilogram fresh weight

was used to convert the fresh weight to dry weight for respective sample area. For determining the actual fodder and firewood yield, 10 plants were randomly picked out of the cut plants from the sample area and then those plants were separated into leaves, stems feedable and non-feedable to animals, particularly cattle, in terms of thickness. After separation, the fresh and oven dry weights of all the components were taken which were later converted into percent basis. Then using the percent distribution of the fodder (leaves and the feedable stems only) in the 10 plants of every sample the actual fodder and firewood yield of the respective sample area was determined.

In 1987, at maximum crop growth stage, light interception by canopy, leaf area index (LAI), and phytomass production per unit area was determined.

For measuring canopy light interception two non-filtered tube solarimeters having an individual length of 0.97 m (Delta-T Devices, England) were used. One tube was placed at the top of the plant canopy with the help of a specially built wooden support and the other was placed beneath the canopy and on the top of the soil surface. But both the tubes were placed across the plant rows in such a way so that the centers of the tubes and the center of the two crop rows were on the same line. Once the tubes were properly placed, then the integrators were switched on and let to run for exactly 10 minutes in every plot, after which the readings were recorded. Finally light interception was determined as follows:

$$\% \text{ Light Interception} = (1 - \frac{l_b}{l_a}) \times 100$$

where: l_b = light below the canopy and l_a = light above the canopy.

For LAI determination, plants of a minimum 0.25 m² having uniform stand at desired spacing and representing the actual plant arrangement were sampled from outside the harvest area but at least 0.75 m inside from the border. Then the leaves were removed and by running those through the Automatic Area Meter (Model AAM-7 of Hayashi Denkoh Co. Ltd. Japan), the total leaf area was determined. Finally LAI was determined by dividing the leaf area with corresponding land area.

Plants sampled for leaf area measurement were also used for determining the phytomass production.

Results and Discussion

During 1986 dry season, all the desired plant density levels could not be maintained due to serious infestation by wilt disease caused by Fusarium udum Butler. Maximum plant mortality was between 3 to 5 weeks after emergence of the seedlings. A few plants continued to die even before maturity of the seeds. Despite this problem, the treatment on row-spacings with only one population level (20 plants m⁻²) was maintained. The crop grew well and the seeds matured in 111 days.

Forty-five centimeter row spacing gave significantly higher grain yield than 0.60 and 0.75 m row spacings (Table 3-2). There was no significant difference between the later two treatments. Yield

Table 3-2. Grain yield of short duration post-rainy season pigeonpea as affected by different row spacings, 1986 dry season, IRRI, Philippines.

Row spacing	Grain yield at 12% moisture
cm	Mg ha ⁻¹
45	1.69 a [†]
60	1.22 b
75	1.28 b
cv (%)	11.50

[†]In a column, means having common letter/s are not significantly different at 0.05 level according to Duncan's New Multiple Range Test.

components were not significantly affected by any of the treatments applied. The average number of pods plant⁻¹, seeds pod⁻¹, 100 seed weight and pod length were 35.5, 4.5, 10.82 g and 0.06 m, respectively. The average plant height at maturity was 0.63 m.

After ratooning the plants produced new branches and some flowers but there was no pod setting probably because of moisture stress. No significant differences were observed among the treatments in terms of fresh and dry fodder weight at any cutting time, and also in terms of dry fire wood yield. The average fodder yields were 1.12, 10.19, 0.40, and 2.03 Mg ha⁻¹ for first and final cut-fresh and first and final cut-dry, respectively. The average dry fire wood yield was 2.96 Mg ha⁻¹.

The 1987 dry season trial was quite alright in terms of stand establishment. Soil moisture level all through the field was uniform. Ground water table was within 1 m from the soil surface for first three months of crop duration; after that the water table went below 1.5 m from the soil surface. Crop growth was very good in general, although some unexplainable poor growth and development was observed in a few plots.

Light interception by canopy, leaf area index (LAI) and dry phytomass data gathered at maximum vegetative growth of the plants are presented in Table 3-3. Significant interaction between row spacings and plant densities were observed in terms of all the three parameters. Light interception was significantly better in the treatments having 30, 40, and 50 plants m⁻² with 0.30 m row spacing compared to other treatments. But those treatments did not differ

Table 3-3. Canopy light interception, leaf area index, and dry phytomass at maximum vegetative growth stage of short duration post-rainy season pigeonpea as affected by different combinations of row spacings and plant densities, 1987 dry season, IRR1, Philippines.

Combinations [†]		Light interception by canopy	Leaf area index (LAI)	Dry phytomass at maximum vegetative growth
RS	PD			
m	plants m ⁻²	%		g m ⁻²
0.30	20	49 cd [‡]	0.8 d	101 d
0.30	30	75 a	1.2 cd	158 cd
0.30	40	74 a	1.5 c	171 cd
0.30	50	72 a	2.9 a	337 a
0.45	20	36 e	1.4 c	178 c
0.45	30	46 de	1.5 c	177 c
0.45	40	49 cd	1.5 c	180 c
0.45	50	59 bc	2.0 b	261 b
0.60	20	49 cd	1.5 c	177 c
0.60	30	54 bcd	1.3 c	174 c
0.60	40	62 b	1.4 c	196 bc
0.60	60	55 bcd	1.5 c	176 c
Significance levels:				
RS		**	NS	NS
PD		**	**	**
RS x PD		*	**	**
cv (%)		10.2	18.5	20.6

*,**Significant at 0.05 and 0.01 levels, respectively. NS = non-significant.

[†]RS = Row spacing; PD = Plant density.

[‡]In a column means having common letter/s are not significantly different at 0.05 level by Duncan's New Multiple Range Test.

among themselves. Significantly higher LAI (2.9) was obtained from 0.30 m row spacing with 50 plants m^{-2} whereas the lowest (0.8) was obtained from 0.30 m spacing with 20 plants m^{-2} . Significantly higher dry phytomass yield (337 g m^{-2}) was also obtained from 0.30 m spacing with 50 plants m^{-2} as compared to the lowest (101 g m^{-2}) from 0.30 m spacing with 20 plants m^{-2} . Based on all the three parameters, 0.30 m spacing with 50 plants m^{-2} was better than all other treatments.

Grain yield data of the main and ratoon crop are presented in Table 3-4. The effect of row spacing was significant in the main crop grain yield; the other effects were insignificant. Treatment having 0.30 m row spacing with 50 plants m^{-2} was significantly better than the treatments having 0.45 and 0.60 m row spacings except the treatments having 0.45 m row spacing with 40 and 50 plants m^{-2} . No significant differences were observed among the treatments in terms of ratoon crop grain yield. The average ratoon crop grain yield was 35% of the average main crop grain yield.

No significant difference was observed between any of the treatments in terms of yield components of the main crop and only pods plant^{-1} of the ratoon crop. The average pods plant^{-1} , seeds pod^{-1} , 100 seed weight, and pod length of the main crop grain yield were 25.4, 4.1, 8.74 g, and 0.05 m, respectively. The average number of pods plant^{-1} of ratoon crop was 28 which is slightly higher than the main crop pods plant^{-1} . The reason for more pods but less grain yield was onset of monsoon rain just at the beginning of grain filling. Due to this plants switched on to profuse vegetative growth by shutting

Table 3-4. Grain yield of the main and ratoon crop of short duration post-rainy season pigeonpea as affected by different combinations of row spacings and plant densities, 1987 dry season, IRRI, Philippines.

Combinations [†]		Grain yield at 12% moisture	
RS	PD	Main crop	Ratoon crop
m	no m ⁻²	Mg ha ⁻¹	
0.30	20	1.59 ab [‡]	0.64 a
0.30	30	1.68 ab	0.59 a
0.30	40	1.72 ab	0.37 a
0.30	50	2.02 a	0.53 a
0.45	20	1.42 b	0.62 a
0.45	30	1.49 b	0.59 a
0.45	40	1.70 ab	0.62 a
0.45	50	1.59 ab	0.41 a
0.60	20	1.48 b	0.74 a
0.60	30	1.48 b	0.63 a
0.60	40	1.48 b	0.49 a
0.60	50	1.57 b	0.50 a

Significance levels:

RS	*	NS
PD	NS	NS
RS x PD	NS	NS
cv (%)	14.20	33.49

*,**Significant at 0.05 and 0.01 levels, respectively. NS = non-significant.

[†]RS = Row spacing; PD = Plant density.

[‡]In a column means having common letter/s are not significantly different at 0.05 level by Duncan's New Multiple Range Test.

off the reproductive growth. As a result, the pods grew but produced few seeds.

Average plant height at maturity of the main crop was 0.63 m. There were no significant differences in terms of fodder yield, both fresh and dry, irrespective of cutting times, and also on the basis of dry firewood yield. The average fodder yields were 1.53, 8.43, 0.51, and 2.36 Mg ha⁻¹ for first and second cut-fresh and first and second cut-dry, respectively. Average dry firewood yield was 2.9 Mg ha⁻¹.

Conclusions

Short duration post-rainy season pigeonpea can be grown successfully under zero tillage conditions in a rainfed lowland following rice in the tropics. The interaction effect of row spacing and plant density was significant for light interception, LAI, and phytomass yield at maximum vegetative growth stage but not for main crop grain yield, which was more affected by row spacing than plant density. The closest row spacing gave significantly better main crop grain yield than wider row spacings. The best treatment in terms of crop grain yield, light interception, LAI, and phytomass production at maximum vegetative growth stage was 0.30 m row spacing with 50 plants m⁻². Ratoon crop grain yield, and fodder and firewood yields were not affected by row spacings and plant densities.

CHAPTER IV
INTERCROPPING SHORT DURATION POST-RAINY SEASON
PIGEONPEA WITH MUNGBEAN AND COWPEA

Introduction

The traditional long duration rainy season pigeonpea is intercropped with different crops in many countries (Aiyer, 1949; Acland, 1971; Arianayagam, 1975; Dalal, 1974). Singh et al. (1979) reported that growing short duration blackgram and greengram as intercrop between the 0.60 m rows of rainfed pigeonpea was profitable. However, intercropping with cowpea was non-profitable. Successful intercropping of rainfed pigeonpea with mungbean was also reported by Saxena and Yadav (1979), Giri and De (1978), Singh and Singh (1980), Giri et al. (1981); Sharma et al. (1981b), Yadav and Yadav (1981), and Singh et al. (1981b). Sharma et al. (1981b) reported that intercropping of pigeonpea with cowpea was not better than sole crop of pigeonpea in terms of total production and net income. But the International Rice Research Institute (IRRI) (1985) reported that pigeonpea + cowpea combination was most promising and gave highest fodder and dry matter yields. No work has been reported on intercropping extra short duration post-rainy season pigeonpea. But Sharma et al. (1981c) mentioned that the possibility of intercropping dry season pigeonpea with mungbean has been observed to be promising. The objective of this study was to determine the productivity and best

intercrop combination of cowpea and mungbean with dry season rainfed pigeonpea.

Materials and Methods

Experiment 2 was conducted at IRRI in an upland simulated rainfed situation following peanut and corn during 1986 and 1987 dry seasons, respectively. Originally this was planned and attempted in dry soil with zero tillage and no fertilizer following lowland rainfed rice. However, in both 1986 and 1987 dry seasons, the plant density levels became extremely uneven due to infestation of wilt disease and repeated typhoons at critical growth stages, respectively. Hence, the trials in the lowland had to be abandoned at a time when it was late for seeding in the rainfed upland also. As a result, to simulate the post-rainy situation for upland, sprinkler irrigation was used as per need and management practices were modified. In this trial pigeonpea (cv QPL 72) was intercropped in additive series with mungbean (cv CES 1D-21) and cowpea (cv TVx-2907-02D) at two levels of intercrop density and two levels of row arrangement. Levels of intercrop density were 100% and 50% of the pure stand density of respective intercrop which were 20 and 40 m⁻² for cowpea and mungbean, respectively. Pigeonpea plant density was 20 and 40 m⁻² for 1986 and 1987, respectively, for both intercrop and solecrop. Levels of row arrangement were one row intercrop in between two rows of pigeonpea and two rows intercrop in between two rows of pigeonpea. There were three treatments for sole crop also which included pigeonpea, mungbean and cowpea. Altogether, there were 11 treatments. Randomized

complete block design was used with three replications. Plot size was 4.80 m x 5.00 m in 1986 and 4.20 m x 5.00 m in 1987.

Row to row spacing in both sole and intercrop plots of pigeonpea during 1986 was 0.60 m. During 1987 for sole crop of pigeonpea, inter-row spacing was changed to 0.45 m but in intercrop 0.60 m was retained. Row spacing in the sole crop of mungbean and cowpea was 0.50 m in both the years.

For the intercrop row arrangement, when there was one row of intercrop in between rows of pigeonpea, the intercrop row was placed in the middle. When there were rows of intercrop in between two rows of pigeonpea, 0.30 m spacing between two rows of intercrop was maintained and both the intercrop rows were placed 0.15 m away from each adjacent pigeonpea row (Fig. 4-1). Within row plant spacing was adjusted according to desired plant density.

The physical and chemical characteristics of the soils of the experimental fields are presented in Table 3-1.

For crop establishment, in both years land was prepared well by plowing and rotovation. Furrows were then opened by using "Lithao" a locally built wooden furrower, and then fertilized, seeded, and covered by hand. Fertilizer application rate was 30-25-50 kg ha⁻¹ of N, P, and K, respectively. Other cultural practices were same to those of in experiment 1 with only exception that in case of mungbean and cowpea, the reseeding and final thinnings were done before 2 WAE.

Date of crop establishment was 7 Feb. 1986 for both 1986 and 1987 dry seasons.

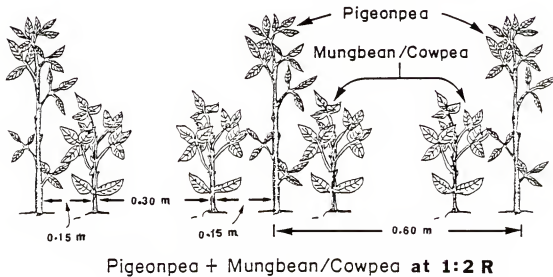
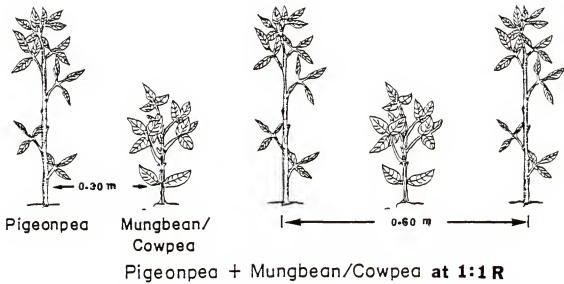


Fig. 4-1. Intercropping of pigeonpea showing row arrangement (R).

At maturity, harvesting, threshing, and data collection on plant height, grain and fodder yield, were done in the way as in experiment 1, with only exception that mungbean and cowpea were not ratooned and fodder yield was estimated right after second picking of the matured pods. Harvest area differed slightly across the treatments and crops due to differences in row spacings. As far as possible an uniform area was harvested. The minimum harvest area for both grain and fodder yield was 10.5 and 7.2 m² in 1986 and 1987 trials, respectively.

At maximum crop growth stage, light interception by crop canopy, LAI and phytomass production per unit land area were determined in the way as done in experiment 1 with only the following exceptions.

1. In case of light interception measurement, three tube solarimeters were used. One was placed on the top of pigeonpea canopy, one on the top of intercrop canopy and the other was on the top of soil surface but below the crop canopy.
2. In case of plant sampling for leaf area measurement, all the plants of an area of 0.50 x 0.50 m for sole crop and 0.60 x 0.50 m for intercrop representing the desired stand and actual spatial arrangement of the plants in respective treatments were sampled.

Records of all field operations, including time and cost of all labor and material inputs and all outputs were maintained for cost and return analysis. Interest at a rate of 4.9% annum⁻¹ on all material cost was charged, and for input and output costs, farm-gate rates were used.

Results and Discussion

Data on leaf area index (LAI), canopy light interception, and dry phytomass gathered at 6 weeks after emergence (WAE) of sole and intercrop combinations of mungbean and cowpea with pigeonpea are presented in Table 4-1. In terms of LAI, significant differences were observed among the sole crops and between intercrops and solecrops in both 1986 and 1987 dry seasons. In 1986, sole cowpea had significantly higher LAI than sole pigeonpea and mungbean. In 1987, it was similar with pigeonpea because of changing the plant density of pigeonpea to 40 plants m^{-2} from that of 20 in 1986, but both pigeonpea (PP) and cowpea (CP) were better than mungbean (MB). Within intercrop combinations, all the interactions between species, plant density, and row arrangement were significant in 1986, whereas in 1987, only the effect of species was significant. This could possibly be due to the increased plant density of pigeonpea in 1987 and also better fertility of the field and less weed problem compared to the field of 1986.

In 1986, pigeonpea intercropped with cowpea gave significantly higher LAI than any solecrop or any combination of pigeonpea and mungbean. The highest LAI was 2.8 obtained from PP + CP with 100% intercrop density (D) and 1:2 row arrangement (R) (Table 4-1). In 1987, the highest actual value of LAI was 4.5 obtained from PP + CP with 50% D and 1:1 R but it was not significantly different from any other combinations of pigeonpea and cowpea. In the case of PP + MB, the best LAI in 1986 was from 100% D with 1:2 R and it was significantly better than sole mungbean or pigeonpea meaning that

Table 4-1. Leaf area index (LAI), canopy light interception and dry phytomass at 6 weeks after emergence of sole and different intercrop combinations of mungbean and cowpea with short duration post-rainy season pigeonpea in a simulated rainfed upland, 1986 and 1987 dry seasons, IRRI, Philippines.

Species† (S)	Treatments		LAI		Canopy light interception		Dry phytomass	
	Intercrop density	Row arrangement						
	(D)	(R)	1986	1987	1986	1987	1986	1987
	%				— % —		— g m ⁻² —	
PP		sole	0.8 g [‡]	3.1 bc	48 c	74 cd	94 e	222 cd
MB		sole	1.1 f	0.9 d	47 c	40 e	110 e	135 d
CP		sole	1.5 d	3.1 bc	65 b	86 ab	171 c	278 bc
PP + MB	100	1:1	1.2 e	2.8 bc	61 b	74 cd	125 d	263 bc
PP + MB	100	1:2	1.4 d	2.7 c	61 b	71 d	149 cd	278 bc
PP + MB	50	1:1	1.2 ef	3.2 abc	41 c	72 cd	122 de	299 abc
PP + MB	50	1:2	1.2 e	2.9 bc	62 b	74 cd	125 de	281 bc
PP + CP	100	1:1	2.1 c	3.9 abc	77 a	89 a	163 c	359 ab
PP + CP	100	1:2	2.8 a	4.2 ab	79 a	89 a	277 a	335 ab
PP + CP	50	1:1	2.0 c	4.5 a	67 b	75 bcd	181 bc	398 a
PP + CP	50	1:2	2.4 b	3.7 abc	80 a	83 abc	208 b	334 ab

Significance levels:

Solecrop	**	**	*	**	**	*
Intercrop vs. solecrop	**	**	**	**	**	**
cv (%)	3.7	23.0	7.4	8.0	11.8	19.8
S	**	*	**	**	**	**
D	**	NS	**	NS	*	NS
R	**	NS	**	NS	**	NS
S x D	*	NS	NS	NS	NS	NS
S x R	**	NS	NS	NS	**	NS
D x R	**	NS	**	NS	**	NS
S x D x R	*	NS	NS	NS	NS	NS
cv (%)	2.9	21.8	7.3	9.0	11.8	18.5

*, ** Significant at 0.05 and 0.01 levels, respectively, NS = nonsignificant.

† PP = pigeonpea, MB = mungbean, CP = cowpea.

‡ In a column, means having common letter/s are not significantly different at 0.05 level by Duncan's New Multiple Range Test.

there was an advantage to intercropping. But in 1987, there was no difference among the PP + MB combinations and the values were not significantly different from the value of sole pigeonpea meaning that contributions to LAI by mungbean in PP + MB combinations were insignificant. Sole cowpea had significantly higher light interception than sole pigeonpea or mungbean in both 1986 and 1987 seasons. Light interception by pigeonpea canopy was statistically the same as mungbean in 1986 but in 1987 it was better because of its increased plant density. Intercrop versus solecrop values were significant in both years meaning that there were significant differences between the intercrop combinations and solecrops in terms of light interception (Table 4-1). Among intercrop combinations in 1986, only D x R interactions and in three main effects--species (S), D and R--were significant. In 1987 only the effect of S was significant. Maximum light interception in both the years was in general by pigeonpea + cowpea combinations. The highest value obtained in 1986 was 80% by PP + CP with 50% D and 1:2 R but it was not significantly different from the PP + CP with 100% D and 1:1 and 1:2 R. In 1987, the highest light interception was 89% which was statistically similar to the values obtained by three PP + CP combinations and the sole cowpea. In 1986, based on light interception values, there were advantages of intercropping cowpea with pigeonpea but in 1987 there was not, since the light interception value of cowpea alone and the best value among PP + CP combinations was the same (Table 4-1). Pigeonpea's role was insignificant and in fact it was totally suppressed by cowpea.

The maximum light interception by PP + MB combinations in 1986 was 61% which was better than the value obtained by either mungbean or pigeonpea alone but in 1987 there was no difference between the values of PP + MB combinations and pigeonpea sole. This means that there was an advantage of intercropping mungbean with pigeonpea in 1986 but not in 1987 and the reason probably is the higher plant density of pigeonpea in 1987.

In terms of dry phytomass, significant differences were observed among the sole crops and also between the sole and intercrops in both 1986 and 1987 seasons. Except S x R and D x R interactions in 1986, no other interactions were significant in any year. The effect of species was only significant in 1987 (Table 4-1). In 1986, sole cowpea had significantly more phytomass than sole pigeonpea or sole mungbean but the latter two were similar. In 1987, sole cowpea was better in phytomass than sole mungbean but was similar to sole pigeonpea, whereas sole pigeonpea and sole mungbean were the same.

Among intercrop combinations, in general PP + CP values were greater than PP + MB values and 1987 values were greater than 1986 values. Among PP + CP combinations in 1986, 100% D with 1:2 R had significantly greater phytomass than any other treatment, which was also greater than cowpea or pigeonpea alone, indicating the advantage of intercropping. In 1987 only one treatment of PP + CP combinations was better than sole cowpea but that was not different from other PP + CP combinations. Hence, it is difficult to find any advantage of pigeonpea in the system, meaning that pigeonpea growth was really suppressed as was observed during field experimentation also,

otherwise the total weight would have been much greater. In the case of PP + MB combinations in 1986, 100% D with 1:2 R was better than sole pigeonpea or sole mungbean but was not different from other PP + MB combinations. In 1987, no difference was observed among PP + MB combinations and also between these combinations and sole pigeonpea, meaning no or very insignificant contributions from mungbean in the intercrop system.

Grain yield obtained from different sole and intercrop combinations are presented in Table 4-2. Mungbean did not cause any significant yield reduction in pigeonpea during 1986. In 1987, significant reduction in grain yield of pigeonpea was caused by mungbean only when it was planted by 1:2 R meaning that at this row arrangement mungbean plants grew better and competed with pigeonpea. Grain yield of mungbean from different intercrop combinations were also significantly less compared to its sole crop grain yield except in the case of 100% D and 1:2 R in 1987 which meant that mungbean growth was affected by pigeonpea. The total grain yield of mungbean and pigeonpea of any of the treatment combinations tested was not better than the grain yield of sole pigeonpea which meant that there was no grain yield advantage for intercropping pigeonpea with mungbean.

Pigeonpea grain yield was significantly reduced compared to its solecrop when intercropped with cowpea in both 1986 and 1987. But cowpea grain yield was not reduced at 100% of its solecrop density when intercropped with pigeonpea in 1986 at 1:1 R. In 1987 it was reduced. At 1:2 R with 100% D, the grain yield of cowpea while

Table 4-2. Grain yield of pigeonpea, mungbean, and cowpea as obtained from sole and different intercrop combinations in a simulated rainfed upland, 1986 and 1987 dry seasons, IRRI, Philippines.

Species	Treatments		Pigeonpea (PP)	
	Intercrop density	Row arrangement	1986	1987
	%		Mg ha ⁻¹	
PP		sole	0.58 a [†]	1.55 a
MB		sole	-	-
CP		sole	-	-
PP + MB	100	1:1	0.45 ab	1.38 ab
PP + MB	100	1:2	0.43 ab	1.01 bcd
PP + MB	50	1:1	0.39 abc	1.34 abc
PP + MB	50	1:2	0.44 ab	1.15 bc
PP + CP	100	1:1	0.21 cd	0.64 dc
PP + CP	100	1:2	0.20 cd	0.20 f
PP + CP	50	1:1	0.26 cd	0.96 cde
PP + CP	50	1:2	0.15 d	0.59 e
cv (%)			31.69	21.08

[†]In a column means having common letter/s are not significantly different at 0.05 level by Duncan's New Multiple Range Test.

Mungbean (MB)		Cowpea (CP)		Total	
1986	1987	1986	1987	1986	1987
Mg ha ⁻¹					
-	-	-	-	0.58 cd	1.55 ab
0.41 a	0.72 a	-	-	0.41 d	0.72 c
-	-	0.99 b	1.62 a	0.99 b	1.62 ab
0.28 b	0.27 b	-	-	0.73 c	1.65 ab
0.16 c	0.47 ab	-	-	0.59 cd	1.48 b
0.24 bc	0.32 b	-	-	0.63 cd	1.66 ab
0.20 bc	0.39 b	-	-	0.64 cd	1.54 ab
-	-	0.95 b	1.11 b	1.16 b	1.75 ab
-	-	1.30 a	1.61 a	1.50 a	1.81 ab
-	-	0.75 c	0.91 b	1.01 b	1.87 a
-	-	1.05 b	1.10 b	1.20 b	1.69 ab
20.91	30.82	9.32	18.97	15.03	10.90

intercropped with pigeonpea was better than its solecrop in 1986 and similar in 1987. This was possibly due to better spatial arrangement which reduced the within row plant competition of cowpea. In terms of total grain yield, only PP + CP with 100% D and 1:2 R gave significantly better grain yield in 1986 than other PP + CP combinations or the related solecrops, whereas in 1987, there were no advantages for intercropping since the total grain yields from any of the PP + CP combinations tested were not better than their related solecrop (Table 4-2).

Use of relative yields and land equivalent ratio (LER) (IRRI, 1974; Willey, 1979) became almost a routine measure and well accepted criteria for quantifying the productive potential of any intercrop system. Hiebsch and McCollum (1987) suggested an improvement over LER, by taking into account the individual crop duration which is area x time equivalent ratio (ATER). This seems more logical for irrigated areas but is not well suited to the rainfed situations where soil moisture is a limiting factor for crop growth and crops may be planted using residual soil moisture just at one particular time of the year. Hence, in this study only relative yields and LER values were determined and presented in Table 4-3. In PP + MB combinations, the relative yield of pigeonpea was higher in general than that of mungbean meaning that in intercrop situations the yield of mungbean was affected more, while in the case of PP + CP combinations, it was pigeonpea which was affected more. Cowpea in a few cases had even higher grain yield than its solecrop and that was possibly due to 1:2 row arrangement which favored the growth and development of cowpea.

Table 4-3. Relative yield (L) of main and intercrop and land equivalent ratio (LER) of different intercrop combinations of mungbean and cowpea with short duration post-rainy season pigeonpea in a simulated rainfed upland, 1986 and 1987 dry seasons, IRRI, Philippines.

Species	Treatments		1986			1987		
	Intercrop	Row	L _{PP}	L _{MB/CP}	LER	L _{PP}	L _{MB/CP}	LER
	density	arrangement						
	%							
PP + MB	100	1:1	0.77	0.69	1.46	0.88	0.39	1.27
PP + MB	100	1:2	0.73	0.40	1.13	0.65	0.66	1.31
PP + MB	50	1:1	0.68	0.61	1.29	0.87	0.46	1.33
PP + MB	50	1:2	0.76	0.50	1.26	0.74	0.58	1.32
PP + CP	100	1:1	0.36	0.96	1.32	0.41	0.70	1.11
PP + CP	100	1:2	0.36	1.31	1.67	0.13	1.01	1.14
PP + CP	50	1:1	0.47	0.76	1.23	0.62	0.58	1.20
PP + CP	50	1:2	0.26	1.06	1.32	0.38	0.70	1.08

In terms of LER, the best treatments among PP + MB combinations were 100% D with 1:1 R and 50% D with 1:1 R in 1986 and 1987, respectively. While in the case of PP + CP, the best were 100% D with 1:2 and 50% D with 1:1 in 1986 and 1987, respectively.

In terms of fodder yield both fresh and dry, in 1986, significant differences were observed among the solecrops and also between intercrops and solecrops. But there was no significant difference among any of the intercrop combinations (Table 4-4). Mungbean had significantly lower fodder yield than pigeonpea which was statistically similar to cowpea though had higher actual value, and that was possibly due to higher coefficient of variation. Highest actual fodder yield was obtained from PP + CP with 100% D and 1:2 R. In 1987 also, significant differences were observed among sole crops and also between sole and intercrop combinations. Some differences were observed among intercrop combinations and that was due to the effect of species. None of the interactions were significant. Like 1986 in 1987 also, significantly lower fodder yield was obtained from mungbean. Pigeonpea gave the highest fodder yield and cowpea was in between. In general, fodder yield was higher in 1987 than 1986 and that is probably due to better crop growth and higher plant density of pigeonpea.

Apart from biological productivity, an attempt has been made to determine the economic productivity also. Due to higher value and production of cowpea, the gross return from sole crop of cowpea and other intercrop combinations involving cowpea were higher than mungbean, pigeonpea solecrop or intercrop combinations in both 1986

Table 4-4. Fodder yield of different intercrop combinations of mungbean and cowpea with short duration post-rainy season pigeonpea in a simulated rainfed upland, 1986 and 1987 dry seasons, IRRI, Philippines.

Treatments			Fodder yield			
Species† (S)	Intercrop density (D)	Row arrangement (R)	Fresh		Dry	
			1986	1987	1986	1987
%			Mg ha ⁻¹			
PP		sole	6.2 ab‡	9.8 cd	1.6 ab	2.0 b
MB		sole	0.3 c	1.6 f	0.1 c	0.4 d
CP		sole	2.5 bc	5.3 e	0.8 bc	1.2 c
PP + MB	100	1:1	5.7 ab	11.0 abc	1.4 ab	2.4 ab
PP + MB	100	1:2	5.6 ab	8.6 d	1.5 ab	2.1 b
PP + MB	50	1:1	7.9 a	10.5 bcd	2.0 a	2.4 b
PP + MB	50	1:2	6.2 ab	10.5 bcd	1.7 ab	2.3 b
PP + CP	100	1:1	7.0 a	13.2 a	1.8 a	3.0 a
PP + CP	100	1:2	9.0 a	11.5 abc	2.4 a	2.5 ab
PP + CP	50	1:1	7.0 a	12.1 abc	1.9 a	2.6 ab
PP + CP	50	1:2	8.3 a	12.5 ab	2.2 a	2.6 ab

Significance levels:

Solecrop	**	**	**	**
Intercrop vs solecrop	**	**	**	**
cv (%)	33.2	13.4	31.2	15.2

Significance levels:

S	NS	**	NS	*
D	NS	NS	NS	NS
R	NS	NS	NS	NS
S x D	NS	NS	NS	NS
S x R	NS	NS	NS	NS
D x R	NS	NS	NS	NS
S x D x R	NS	NS	NS	NS
cv (%)	38.8	12.6	35.3	14.3

*,**Significant at 0.05 and 0.01 levels, respectively, NS = nonsignificant.

†PP = pigeonpea, MB = mungbean, CP = cowpea.

‡In a column, means having common letter/s are not significantly different at 0.05 level by Duncan's New Multiple Range Test.

and 1987 (Table 4-5). Total variable costs were slightly higher in intercrops compared to solecrops which was due to additional seeds and labor for planting and harvesting.

Production of mungbean as solecrop was not profitable in either year. As intercropped with pigeonpea it was slightly profitable in 1987 but was not profitable in 1986 (Table 4-6). Pigeonpea as solecrop also was not profitable in 1986 but in 1987 it became slightly profitable. Cowpea was the only crop in sole culture that was profitable in both the years. In 1986, the highest net return both in terms of dollars ha^{-1} and dollar per dollar investment was from PP + CP with 100% D and 1:2 R which was followed by cowpea sole. In 1987 the highest profit was from sole cowpea and the second highest was from PP + CP with 100% D and 1:2 R.

Conclusions

Based on LAI, light interception, and dry phytomass at 6 WAE, it can be concluded that in 1986, intercropping of mungbean and cowpea with pigeonpea was advantageous. As an intercrop cowpea was better than mungbean. In the case of both mungbean and cowpea, best intercrop treatment was 100% D with 1:2 R. But in 1987, intercropping was not advantageous. Contribution of mungbean in the intercrop output was insignificant probably due to higher density of pigeonpea. In the case of cowpea, the reverse happened--pigeonpea was suppressed. This was possibly because of better fertility and less weed growth in the field during 1987. In terms of grain yield, the same trend was observed. Mungbean was affected by pigeonpea while pigeonpea was

Table 4-5. Gross return and total variable costs of different intercrop combinations of mungbean and cowpea with short duration post-rainy season pigeonpea in a simulated rainfed upland, 1986 and 1987 dry seasons, IRRI, Philippines.

Species	Treatments		Gross return†		Total variable costs‡	
	Intercrop density	Row arrangement	1986	1987	1986	1987
	%		\$ ha ⁻¹			
PP		sole	311	835	611	722
MB		sole	240	420	671	459
CP		sole	679	1111	572	632
PP + MB	100	1:1	403	900	609	748
PP + MB	100	1:2	322	819	680	772
PP + MB	50	1:1	351	907	639	783
PP + MB	50	1:2	353	847	759	767
PP + CP	100	1:1	763	1103	689	764
PP + CP	100	1:2	995	1210	690	786
PP + CP	50	1:1	649	1138	701	826
PP + CP	50	1:2	796	1070	731	793

†Farmgate cost of produce (\$ kg⁻¹): PP = 0.54, MB = 0.59, CP = 0.68.

‡Farmgate cost of seeds (\$ kg⁻¹): PP = 0.88, MB = 0.83, CP = 0.88.

Table 4-6. Net returns from different intercrop combinations of mungbean and cowpea with short duration post-rainy season pigeonpea in a simulated rainfed upland, 1986 and 1987 dry seasons, IRRI, Philippines.

Treatments			Net return			
Species	Intercrop	Row	ha ⁻¹		\$ ⁻¹ investment	
	density	arrangement	1986	1987	1986	1987
	%				\$	
PP	-	sole	-300	113	-0.49	0.16
MB	-	sole	-431	-39	-0.64	-0.08
CP	-	sole	107	479	0.19	0.76
PP + MB	100	1:1	-206	152	-0.34	0.20
PP + MB	100	1:2	-358	47	-0.53	0.06
PP + MB	50	1:1	-288	124	-0.45	0.16
PP + MB	50	1:2	-406	80	-0.54	0.10
PP + CP	100	1:1	74	339	0.11	0.44
PP + CP	100	1:2	305	424	0.44	0.54
PP + CP	50	1:1	-52	312	-0.07	0.38
PP + CP	50	1:2	65	277	0.09	0.35

affected by cowpea. So, there was no grain yield advantage for intercropping pigeonpea with mungbean. In the case of cowpea, however, in 1986, 100% D with 1:2 R showed grain yield advantage over other treatments. A LER value of 1.67 was also obtained from the same PP + CP combination in 1986 but in 1987, LER values were not very high from any of the combinations tested.

Solecrops differed significantly in terms of both fresh and dry fodder yield in both the years but intercrop combinations did differ only in 1987 but not in 1986. Highest actual fodder yield was from PP + CP with 100% D and 1:2 R. The same treatment was better in 1986 based on net return whereas sole cowpea was the best in 1987.

Mungbean may not be used for intercropping with pigeonpea under rainfed upland situations. Cowpea, if used, must be done under lower fertility and moisture situations in 100% D with 1:2 R for maximum productivity. At higher moisture and fertility levels, cowpea suppressed the pigeonpea growth and in that case sole cowpea was better than intercropping.

CHAPTER V
PRODUCTIVITY AND METHODS OF RATOONING SHORT DURATION
POST-RAINY SEASON PIGEONPEA

Introduction

Depending on interest, ratooning can be done either for additional forage yield, seed yield, or for both. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (1977) reported that highest second harvest seed yield came from the non-ratooned plants whereas the lowest seed yield came from the plants which were ratooned closest to the ground. Similar observations were also reported by Venkataratnam and Sheldrake (1985). According to them, the seed yield reductions due to ratooning closer to the ground were due to both greater mortality of the plants and greater delay in the development of the second flush of pods. Tayo (1985) concluded that ratooning pigeonpea leads to significantly higher seed yield than harvesting once, and cutting the main stem back to 0.30 m is the best form of ratooning under lowland tropical conditions. All of this work was done with either long or medium duration cultivars planted during the rainy season. No work has been reported on short duration cultivars grown particularly under rainfed lowland rice-based situations where moisture stress becomes progressively greater with the passing of time. Hence, this present study was undertaken with an objective to determine the productivity and methods of ratooning short duration pigeonpea under lowland rainfed rice-based systems.

Materials and Methods

Experiment 3 was conducted in the lowland following rainfed rice during 1986 and 1987 dry seasons at IRRI. The physical and chemical properties of the soils of the experimental fields are presented in Table 3-1.

There were three treatments on ratooning which included 20, 40 and 60% crop canopy removal by cutting the shoot terminals from all sides in a dome shape after hand picking of all the matured pods. There was also one control treatment in which after hand picking of all the matured pods the plants were left uncut. Cutting was done by sickle. The experimental design used was a randomized complete block with three replications. Plot size was 5.00 x 4.80 m and 5.00 x 4.50 m in 1986 and 1987 seasons, respectively.

Crop establishment technique, fertilizer applications and other cultural practices were same to those of in experiment 1. In the 1986 trial, plant density and row to row spacing was 20 m^{-2} and 0.60 m, respectively, whereas in 1987 trial these were changed to 40 m^{-2} and 0.45 m, respectively.

Dates of crop establishment and ratooning were 27 Dec. 1985 and 2 May 1986, respectively, for 1986 dry season, and 20 Dec. 1986 and 15 Apr. 1987, respectively, for 1987 dry season.

At maturity, harvesting, threshing, data collection on grain and fodder yields, and yield components were done in the way described in experiment 1. Data on ratooning time, plant height, mortality, and primary branch development as influenced by ratooning were also recorded. In addition, during 1987 before harvest of ratoon crop,

leaf counts, and dry weight of leaves and stems separately for three plants plot⁻¹ were also taken. Harvest area for both grain and fodder yield was 9.60 and 8.10 m² during 1986 and 1987 dry seasons, respectively.

Results and Discussion

The effect of different ratooning treatments on ratooning time, plant mortality, and primary branch counts are presented in Table 5-1. In both years, significantly more ratooning time was required for 20% canopy cut compared to 40 and 60% cuts. This was because of more time taken to look, hold and cut separately the shoot tips which very often were not of the same height. On the other hand, for 40 and 60% cuts, holding all the branches together was easier. There is no significant difference among the treatments in terms of plant mortality, which means that the small percentage of plants which died in both the years was not due to ratooning. It was possibly due to the moisture stress which was quite high during that time. Number of primary branches plant⁻¹ at harvest of ratoon crop was not affected by ratooning treatments in 1986 dry season. But in 1987 dry season, significantly fewer branches were found on the plants ratooned by 40 and 60% canopy cuts as compared to no cut. These data confirm the field observation that cutting closer to the ground reduces the number of primary branches but increases the number of secondary and tertiary branches.

Percent increase in plant height after ratooning increased with increasing percent of canopy cut meaning that more vegetative growth took place in cases where the plants were cut lower or deeper

Table 5-1. Ratooning time, plant mortality, and primary branches of short duration, post-rainy season pigeonpea as affected by different ratooning treatments, 1986 and 1987 dry seasons, IRRI, Philippines.

Treatments	Ratooning time		Plant mortality 3 weeks after ratooning		Primary branches at harvest of ratooned crop	
	1986	1987	1986	1987	1986	1987
	— md ha ⁻¹ —		— % —		— No. plant ⁻¹ —	
Control	-	-	9 a	14 a	5 a	7 a
20% canopy cut	64 a [†]	19 a	5 a	11 a	4 a	6 ab
40% canopy cut	41 b	14 b	9 a	8 a	4 a	4 b
60% canopy cut	50 b	11 b	9 a	10 a	4 a	4 b
cv (%)	10.5	12.5	42.9	55.2	20.1	26.8

[†]In a column, means having common letter/s are not significantly different at 0.05 level according to Duncan's New Multiple Range Test.

(Table 5-2). Treatments with 40 and 60% canopy cut had significantly higher increases in plant height compared to no cut in both the years. Treatment with 20% canopy cut had actual value higher than control and lower than 40% cut in both years, but statistically there was no difference between control and 20% cut, and 20 and 40% cuts.

The main crop growth was quite uniform in both the years. The average main crop grain yield was 1.23 and 1.44 Mg ha⁻¹ for 1986 and 1987 dry seasons, respectively. In 1986 dry season, both ratooned and non-ratooned plants kept on flowering for a few weeks but there was no pod set, probably because of moisture stress. Ground water table during that period was more than 1.5 m away from the soil surface. Soil at 0.30 m depth had 23% moisture as determined by gravimetric method. In 1987 dry season, the soil moisture situation was a little better than 1986 because of underground seepage of water from a nearby irrigation block. Though ground water table was more than 1.5 m away from the soil surface yet the field had good moisture in the soil profile. During the entire dry season soil moisture from 0.30 to 1.50 m depth varied from 30 to 70%. Moreover, during the 1987 dry season the average air temperature and relative humidity were higher and lower, respectively, compared to those of 1986 dry season. As a result there were very good flowering and pod setting in 1987 dry season ratoon crop.

Plants in the control plots flowered earlier and completed 80% flowering within one month from the date of main crop pod picking. The ratooned plants flowered late. For every ratooning treatment with the increase in 20% canopy cut, there was at least one week delay in

Table 5-2. Increase in plant height, grain yield, pods plant⁻¹, and firewood yield of short duration post-rainy season pigeonpea as affected by different ratooning treatments, 1986 and 1987 dry seasons, IRRI, Philippines.

Treatments	Increase in plant height after ratooning		Grain yield	Pods plant ⁻¹	Dry firewood yield	
	1986	1987	1987	1987	1986	1987
	—————	% —————	Mg ha ⁻¹		—————	Mg ha ⁻¹ —————
Control	118 c†	83 c	1.5 a	28 a	3.1 a	2.8 a
20% canopy cut	193 bc	113 bc	1.0 ab	29 a	2.9 a	2.2 a
40% canopy cut	221 ab	148 b	0.8 b	14 b	2.6 ab	2.3 a
60% canopy cut	291 a	322 a	0.4 b	5 c	2.1 b	2.4 a
cv (%)	20.3	12.3	36.1	19.0	13.3	26.4

†In a column, means having common letter/s are not significantly different at 0.05 level according to Duncan's New Multiple Range Test.

flowering. The treatment with 60% canopy cut flowered 3 weeks later than the plants having no cut. As a result, the flowering could not be carried on smoothly due to onset of monsoon rain which lowered the atmospheric temperature, increased the relative humidity and soil moisture to a point where plants switched over to profuse vegetative growth. For this reason there were significant differences in grain yield and pods plant⁻¹ in 1987 dry season ratoon crop (Table 5-2). Highest second harvest grain yield (1.5 Mg ha⁻¹) was obtained from the non-ratooned plants, meaning that if soil moisture condition is expected to be favorable then it would be better not to ratoon the plants. Second harvest grain yield from the control plants was also slightly higher than the first harvest grain yield. Lowest second harvest grain yield came from the plants that were ratooned more, i.e., received 60% canopy cut. These findings confirm similar results reported by ICRISAT (1977) and Venkataratnam and Sheldrake (1985). A total of 2.9 Mg ha⁻¹ grain yield was obtained by two harvests from the short duration post-rainy season pigeonpea that were not ratooned, and in which the first harvest was done by hand picking. Significantly lower number of pods plant⁻¹ were obtained also in case of 40 and 60% canopy cut compared to no cut and 20% cut which were, however, similar to each other. No significant difference was observed, however, in the case of seeds pod⁻¹, 100 seed weight, and pod length.

In 1986 dry season, plants having 60% canopy cut gave significantly lower firewood yield compared to plants with no cut or 20% cut. This was because of less woody or thicker branches in the plants of this treatment compared to the plants of other treatments.

There was no significant difference among the treatments in terms of dry firewood yield in 1987 dry season (Table 5-2).

In terms of first cut fresh fodder yield, in both the years there were treatment differences. Increased cutting gave significantly higher fodder yields except in the case of 20 and 40% cuts in 1986 dry season in which case the fodder yield was statistically the same (Table 5-3). During final cuts, there were no significant differences in between any of the treatments within any one year. The time passed from first to the second cut were 2 and 2.5 months in case of first and second year study, respectively. During these periods in both the years, ratooned plants were able to compensate their losses of phytomass in first cut and got uniform with the control plants. There were no treatment differences in terms of total fresh fodder yield in 1986 dry season. But in 1987, 60% cut gave significantly higher total fresh fodder yield than other treatments. The highest and lowest total fresh fodder yields obtained were 13.1 and 8.3 Mg ha⁻¹ from the plots receiving 60% canopy cut and no cut treatments, respectively (Table 5-3).

Data on dry fodder yield followed exactly the same trend of fresh fodder yield. The highest and lowest total dry fodder yield obtained were 3.6 and 2.0 Mg ha⁻¹ from the plants having 60% canopy cut and no cut, respectively (Table 5-4).

No significant difference was observed between any of the treatments during 1987 season in terms of the number and dry weight of leaves, dry weight of stems, and leaf-stem ratio plant⁻¹. The average values of those parameters were 144, 5.83 g, 14.69 g, and 0.40, respectively.

Table 5-3. Fresh fodder yield of short duration post-rainy season pigeonpea as affected by different ratooning treatments, 1986 and 1987 dry seasons, IRRI, Philippines.

Treatments	First cut		Final cut		Total	
	1986	1987	1986	1987	1986	1987
	Mg ha ⁻¹					
Control	-	-	8.9 a	8.3 a	8.9 a	8.3 b
20% canopy cut	1.6 b [†]	0.9 c	8.4 a	7.8 a	10.0 a	8.7 b
40% canopy cut	1.8 b	1.4 b	9.0 a	7.9 a	10.8 a	9.3 b
60% canopy cut	2.5 a	3.5 a	8.3 a	9.6 a	10.8 a	13.1 a
cv (%)	10.1	11.5	15.0	11.2	12.8	10.4

[†]In a column, means having common letter/s are not significantly different at 0.05 level according to Duncan's New Multiple Range Test.

Table 5-4. Dry fodder yield of short duration post-rainy season pigeonpea as affected by different ratooning treatments, 1986 and 1987 dry seasons, IRRI, Philippines.

Treatments	First cut		Final cut		Total	
	1986	1987	1986	1987	1986	1987
	Mg ha ⁻¹					
Control	-	-	2.0 a	2.0 a	2.0 a	2.0 b
20% canopy cut	0.6 b [†]	0.3 c	1.8 a	2.0 a	2.4 a	2.3 b
40% canopy cut	0.7 b	0.4 b	2.0 a	2.1 a	2.7 a	2.5 b
60% canopy cut	0.9 a	1.2 a	1.7 a	2.4 a	2.6 a	3.6 a
cv (%)	10.1	11.0	12.5	11.9	8.3	11.6

[†]In a column, means having common letter/s are not significantly different at 0.05 level according to Duncan's New Multiple Range Test.

Conclusions

Productivity of the ratoon crop of short duration post-rainy season pigeonpea following lowland rainfed rice depended mainly on the soil moisture conditions that existed after the first harvest of grain or ratooning. If the soil moisture remains favorable (at least 30 to 35% moisture at 0.30 m depth in clay soil) then plants will probably flower and produce second set of grain, otherwise they will continue to maintain slow growth until the rain starts. Ratooning delayed the flowering and pod bearing due to required vegetative regrowth, hence, under favorable soil moisture conditions, no cut or keeping the plants as they are after hand picking of the main crop pods is recommended for higher second harvest grain yield. Ratooning did not cause any significant plant mortality. Hence, when only fodder and firewood yields are expected then 40 or 60% canopy cut would be better in terms of ratooning time compared to zero or 20% cut.

Under favorable soil moisture conditions, a total of 2.9 Mg ha^{-1} grain yield was possible by two harvests from the plants having no cut. The second harvest of grain was slightly higher than the first harvest. All treatments and two season average dry fodder and firewood yields were 2.5 Mg ha^{-1} for each.

CHAPTER VI
COMPARISON OF DIFFERENT CROPPING PATTERNS
ON RAINFED LOWLAND AREAS OF THE PHILIPPINES

Introduction

In the Philippines during the post-rainy season in lowland rice-based environments, farmers occasionally grow mungbean and/or cowpea. But they have never tried pigeonpea. Traditionally, pigeonpea has been a long duration rainy-season crop. However, development of early and extra early cultivars has expanded opportunities for pigeonpea cultivation. In 1979, Narayanan and Sheldrake reported that pigeonpea has potential as a post-rainy season crop. Narayanan et al. (1981) reported that in rice fields in the post-rainy season, where irrigation is not possible, pigeonpea can be grown successfully with a minimum of fertilizer and other cultural inputs. According to Sheldrake (1984), under short day and low temperature conditions of the post-rainy season, the reduced duration and growth of the pigeonpea plants enables them to be grown at high densities and to be managed as ordinary annual crops. He further reported that ratooning of the pigeonpea plants to get a second grain yield is also possible. Hence, this study was undertaken to compare the selective advantages of growing pigeonpea alone or in an intercrop situation following rice compared to other cropping patterns in different agro-climatic situations.

Materials and Methods

Experiment 4 was conducted during 1985-86 and 1986-87 seasons in five farmers' fields at five locations in Central Luzon and one field at IRRI Laguna. Laguna is mainly irrigated, but its rainfall pattern is little different than that of other selected locations. Hence, a rainfed lowland field was selected at IRRI (Laguna). The locations in central Luzon were as follows:

<u>Barangay (Village)</u>	<u>Municipality</u>	<u>Province</u>	<u>Region</u>
Carosucan	Sta. Barbara	Pangasinan	I
Bantug (BTG)	Guimba	Nueva Ecija	III
Makapilapil (MPL)	San Ildefonso	Bulacan	III
San Miguel (SML)	Guimba	Nueva Ecija	III

Geographical location:

<u>Barangay (Village)</u>	<u>Latitude</u>	<u>Longitude</u>
Carosucan	16°0'N	120°24'E
Bantug (BTG)	15°39'N	120°47'E
Makapilapil (MPL)	16°0'N	120°24'E
San Miguel (SML)	15°39'N	120°47'E

There were two fields at Carosucan—one was of light soil (CLS) and the other was of heavy soil (CHS). In the second year, the study was discontinued at MPL, instead a new field was taken at SML. All the locations are shown in Fig. 6-1 with average rainfall of at least 20 years. The physical and chemical characteristics of the soil of all the fields under this trial are presented in Table 6-1.

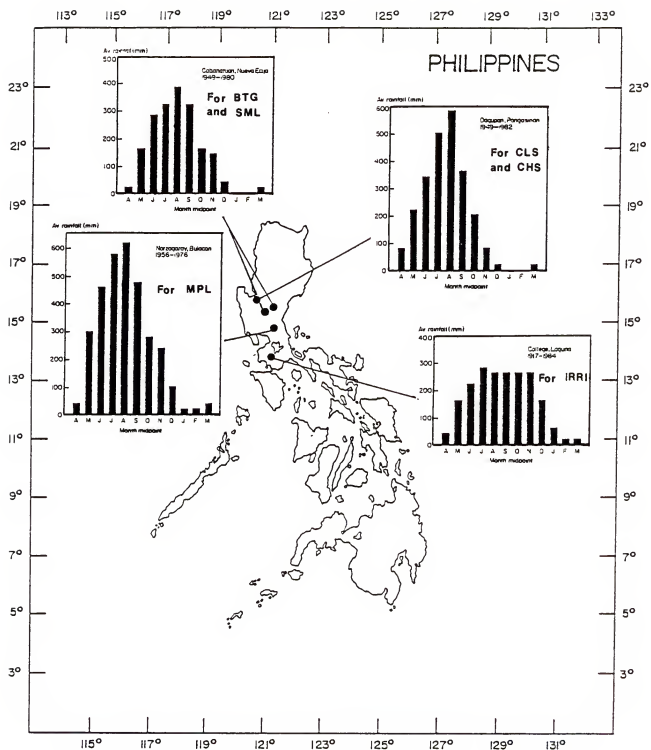


Fig. 6-1. Locations for cropping pattern testing showing the average rainfall for at least 20 years.

Table 6-1. Physical and chemical characteristics of the soil of all the fields used for conducting experiment four, IRRI, Philippines.

Field No.	Year	Particle size			pH 1:1 w/v H ₂ O	Org. C (%)	CEC meq/ 100 g ads†	Total N (%)	Avail. P	Exch. K
		Clay (%)	Silt (%)	Sand (%)					(Olsen) ppm ads	meq/ 100 g ads
IRRI:										
N-4	85-86	46	43	11	6.5	1.05	32.4	0.116	20.0	0.811
E49(A)	86-87	47	40	13	6.2	1.22	33.6	0.125	36.0	0.950
BTG	85-87	27	47	26	6.5	1.07	23.2	0.094	7.8	0.207
CLS	85-87	13	65	22	6.2	0.86	11.3	0.057	5.7	0.110
CHS	85-87	33	61	6	6.7	1.27	25.8	0.095	7.4	0.257
MPL	85-86	19	51	30	4.9	0.57	9.2	0.060	1.4	0.106
SML	86-87	68	30	2	5.5	1.32	48.0	0.106	11.0	0.358

[†]ads = air-dried soil.

The selection of locations outside IRRI, Laguna was mainly based on the following criteria:

1. Should be a rainfed lowland situation with big extrapolation area.
2. Farmers' existing main cropping pattern is single transplant rice.
3. Easily accessible in the area and can be operated from IRRI with few difficulties.

In selecting a field, the following criteria were maintained:

1. The area should be at least 1000 m², reasonably level, have no history of any soil problem, ownership dispute and be farmed by land owner.
2. The farmer is cooperative and willing to cooperate in the test program for at least 2 years.

The experiment was conducted as both researcher and farmer managed trials in a randomized complete block design with three replications in each field. The plot size was a minimum 40 m² during the wet season and 33 m² during the dry season in both years. In each field or location, five test patterns were compared with farmers' existing cropping patterns which were transplant rice (TPR)-fallow at all locations except fallow or mungbean at Carosucan only. Test patterns included:

TPR-Cowpea ('TVx 2724-01F')

TPR-Mungbean ('CES 1D-21')

TPR-Pigeonpea ('QPL72') ratooned

TPR-Pigeonpea ('QPL72') ratooned + cowpea ('TVx 2907-02D')

TPR-Pigeonpea ('QPL72') ratooned + mungbean ('CES 1D-21')

For rice, except at IRRI, land preparation was done by the farmer. Plot layout was such that a reasonably sizeable area was left outside the experiment to enable the farmers to produce their crop in their way without being affected by any sort of obligation or fear of damaging the main experiment. In addition, the plots to receive the farmers' pattern inside the experiment were also marked and shown to the farmers so that they could produce their crop in the same way they would be doing in the adjacent area outside the experiment and also in their other fields. After this, all the plots receiving test patterns and the farmers' patterns were managed by researcher and farmer, respectively. For the farmers' pattern since management factors and levels were not predetermined, all field operations were monitored and data gathering was done from the plots both inside and outside the layout and an average was made. The same was done for the dry season crop.

For the dry season crop, since farmers' practices at Pangasinan required a large area for land preparation, farmer cooperators' other fields adjacent to the test fields were monitored and used for crop cutting and data gathering.

At IRRI, the farmer's practice of BTG was simulated. However, everything was managed by researchers.

For TPR in the test patterns--cultivar use, fertilizer application and other cultural practices made were based on the latest research recommendation for the respective areas.

For dry season crops of the test patterns the same cultivars for each and same management practices were followed at all locations.

Crop establishment and fertilizer application were similar to those in experiment 1. Plant density and other cultural practices were similar to those in experiment 2 with the exception that no weeding was given in the second year if it was not required by the crop situation. For intercropping of pigeonpea with cowpea and mungbean, a 1:1 row arrangement was used with 100% plant density of the respective sole crop. Pigeonpea lines were planted 0.60 m apart in intercrop plots.

At maturity, grain and fodder harvest, ratooning of pigeonpea and second harvest of fodder were done in the same way as in experiment 2.

Sample area for grain and fodder harvest was at least 20 m² per plot. At all locations, records of all operations including the quantity and cost of all inputs and outputs were maintained for the purpose of economic analysis.

Data on plant height, grain and fodder yield were recorded. During the dry season, soil moisture was monitored at approximately two week intervals at 0.30 m depths by the gravimetric method. A piezometer was installed in every field during the dry season and the position of the water table was monitored every week from planting of the dry season crops until the water table went deeper than 1.5 m from the soil surface. Data on rainfall, and maximum and minimum temperature of all locations were gathered from the location or from the nearest meteorological station of PAGASA (The Philippine Atmospheric, Geophysical and Astronomical Services Administration).

For comparison of different cropping patterns across the test locations, modified stability analysis and distribution of confidence intervals (Hildebrand, 1982) were used.

Results and Discussion

Since this study involved year-round cropping in different agro-climatic situations, before describing the results a brief description of each environment is given below to enable better understanding of the results.

IRRI

The soil here was silty clay with 1.05% organic matter and a pH of 6.5. Rainfall, air temperature, relative humidity, solar radiation, and pan evaporation data for 1985-86 and 1986-87 are presented in Figs. 6-2 to 6-4. Astronomically possible maximum sunshine duration at IRRI is also provided in Fig. 6-4. Other test locations will have limited weather data, but the information provided in Fig. 6-2 would give a general impression which may be used with due consideration for other test locations also. Except year to year slight variation there was no major change in any weather parameters at IRRI during the test years compared to other years. August rainfall was slightly lower than normal during the test years but it did not affect the rice crop. There were several typhoons in both the years which occurred during June-July and October-December but did not cause any damage to the crop of this trial at this location. This location had at least 7 wet months during both the test years. Rainfall stopped late in December or mid-January. There were few light showers during the dry season in both the years at this location which normally cannot be expected in other test locations. Ground water table went deeper than 1.5 m from soil surface within 2 months

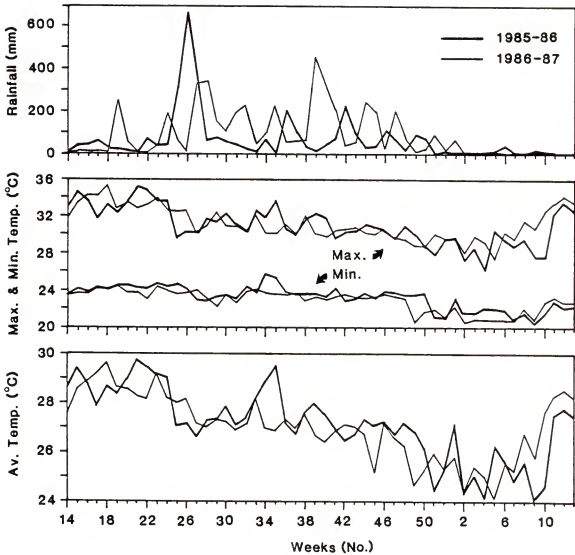


Fig. 6-2. Weekly average rainfall, and maximum, minimum and average air temperature for 1985-86 and 1986-87 seasons at IRRI, Philippines.

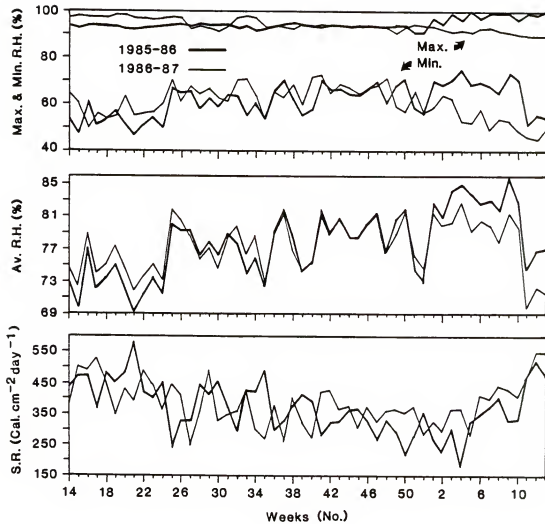


Fig. 6-3. Weekly average maximum, minimum and average relative humidity (R.H.) and solar radiation (S.R.) for 1985-86 and 1986-87 seasons at IRRI, Philippines.

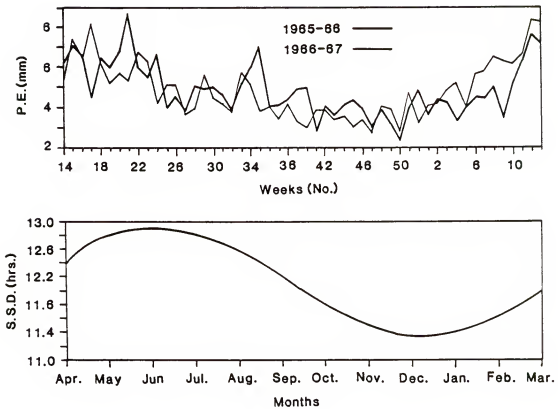


Fig. 6-4. Weekly average pan evaporation (P.E.) for 1985-86 and 1986-87 seasons and astronomically possible sunshine duration (S.S.D.) at IRRI, Philippines.

of the establishment of legume crops in both years but even after that the soil profile had a good amount of moisture which was possibly due to underground water seepage from nearby irrigated blocks particularly during the 1987 dry season.

Makapilapil (MPL)

The soil here was silty loam with 0.57% organic matter and a pH of 4.9. This is a low lying basin type area. Water ponding in the field during the rainy season varied from 0.10 to 0.15 m. Rain water from other nearby areas and mountains runs over this area which probably caused the soil to be acidic. Long term average rainfall of Norzagaray, Bulacan, the nearest to this location, is higher than the rainfall of other test locations (Fig. 6-1). There were no major changes in the weather at this location during 1985-86 season. During the dry season, the ground water table went deeper than 1.5 m within 2 months of crop establishment.

Bantug (BTG)

This location had loamy soil with 1.07% organic matter and a pH of 6.5. The rainfall and air temperature charts of this location are presented in Fig. 6-5. In 1986-87, the rainfall here was quite low compared to 1985-86. In October 1985, this area was worst hit by a typhoon. The dry season trial was totally damaged at the seedling stage, and it was necessary to plant again. In December, 1986, when the legumes were at the seedling stage, heavy typhoon rains flooded the entire field. The plants survived but could not

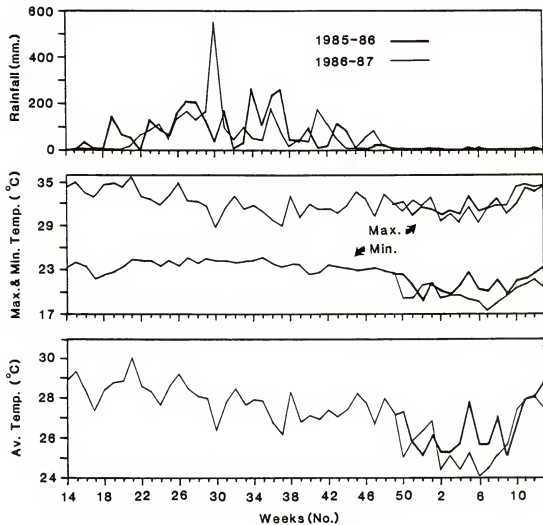


Fig. 6-5. Weekly average rainfall for 1985-86 and 1986-87, and maximum, minimum and average air temperature for part of 1985-86 and full of 1986-87 at BTG, Nueva Ecija, Philippines.

recover from the stress of excessive moisture. There was also no time to replant the whole trial. But normally, this location is the driest one compared to all other test locations.

San Miguel (SML)

The soil here was clay with 1.32% organic matter and a pH of 5.5. This area also gets washed out every wet season by rain water from other higher elevated areas like MPL. This area was about 20 to 25 kms from BTG and had almost the same rainfall and temperature. But this area appeared to be less dry than BTG possibly due to its heavier clay soil, holding more moisture. The ground water table at both BTG and SML dried to the 1.5 m depth within 2 to 2 1/2 months after rain stopped.

Carosucan (CLS) and (CHS)

The CLS and CHS fields were at the same location but different in elevation and soil texture. The CLS area had silt loam soil with 0.86% organic matter and 6.2 pH whereas CHS had 1.27% organic matter and 6.7 pH. CHS was lower in elevation and as a result had higher water ponding during the wet season compared to CLS. The soil also dried more slowly during the dry season compared to CLS. The rainfall and air temperature gathered from the nearest weather station at Dagupan are presented in Fig. 6-6. There were no major weather abnormalities except a few typhoons during the test years. The 1987 dry season crop at CHS was destroyed by typhoon and heavy rains at seedling emergence stage, so it had to be replanted again. The ground water table dried

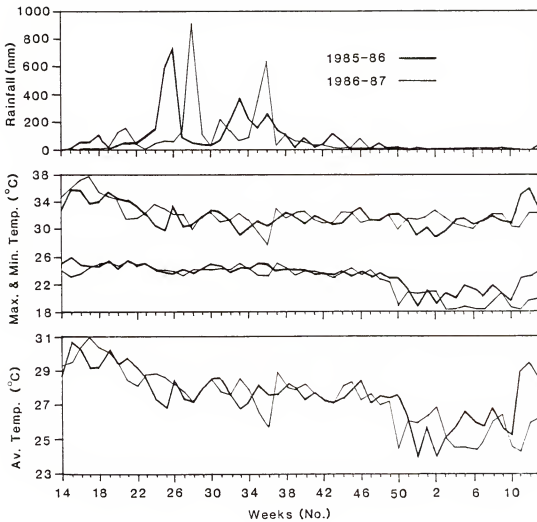


Fig. 6-6. Weekly average rainfall, and maximum, minimum, and average air temperature for 1985-86 and 1986-87 seasons at Dagupan, Philippines, for CLS and CHS.

down to a depth of 1.5 m approximately within a month in CLS and within 2.5 months in CHS from the date of the last good rain.

In general, mid-October to mid-December was the peak time for typhoons in all the test locations. Unfortunately this was also the peak time for establishing the legume crop following rice. So, in all the test locations, there was some risk involved in establishing the legume crops following rice.

For convenience of better understanding of these results, rice data will be presented and discussed first followed by legume data and finally an effort will be made to put both data together.

First Crop: Rice

Grain yields obtained are presented in Table 6-2. In the 1985 wet season, yield of rice was significantly better in the tested patterns compared to farmers' at IRRI, BTG, and CLS. This was mainly due to the new cultivar IR64. Farmers used higher seed rates and closer random plantings in all these three locations (Table 6-3) but still IR36 could not do better than IR 64. In the case of CHS and MPL, the grain yields were statistically the same. At these locations, IR42 was used in both farmers' and tested cropping patterns. Farmers used a high seed rate meaning higher plant population per unit area at all locations. As a result, in the farmers' plots weeding requirement was less compared to the plots having tested patterns but grain yield was the same. The first year's experience in rice production indicated that by random transplanting at approximately 0.17 x 0.17 m spacings, farmers reduced the weeding

Table 6-2. Grain yield of rice crop of farmers' and tested cropping patterns grown with farmers' and recommended practices, respectively, at different test locations, 1985 and 1986 wet seasons, IRRI, Philippines.

Cropping patterns	IRRI		BTG		CLS		CHS		MPL	SML
	1985	1986	1985	1986	1985	1986	1985	1986	1985	1986
	Mg ha ⁻¹									
Farmers'	4.2 b [†]	3.6 a	2.9 b	4.6 a	3.9 b	4.4 a	4.8 a	5.5 a	5.0 a	5.3 b
Tested	5.4 a	3.6 a	4.3 a	5.2 a	4.0 a	5.4 a	5.0 a	5.8 a	5.4 a	6.0 a
cv (%)	1.6	8.1	5.5	9.0	0.5	6.5	2.2	2.7	3.6	0.8

[†]In a column, means having common letter are not significantly different at 0.05 level by Duncan's New Multiple Range Test.

Table 6-3. Cultural and management practices used in rice crop of farmers' and tested cropping patterns grown with farmers' and recommended practices, respectively, at different test locations, 1985 wet season, IRRI, Philippines.

Cultural and management practices†	IRRI‡		BTG	
	FP	RP	FP	RP
Cultivar/line used	IR36	IR64	IR21015	IR64
Plowings (no.)	2	2	1	1
Harrowings (no.)	2	2	2	2
Seeding rate (kg ha ⁻¹)	80	45	100	45
Seedlings age (days)	20	20	26	26
Transplanting date	16 Jul 85	16 Jul 85	22 Jul 85	22 Jul 85
Transplanting method (m x m)	random	0.20x0.20	random	0.20x0.20
N-P-K rate (kg ha ⁻¹)	50-11-21	60-0-0	45-8-15	55-11-0
During LP (kg ha ⁻¹)	25-11-21	40-0-0	-	35-11-0
10 to 30 DAP (kg ha ⁻¹)	-	-	45-8-15	-
At PI (kg ha ⁻¹)	25-0-0	20-0-0	-	20-0-0
Hand weeded (time/s)	1	2	0	1
Used insecticide (time/s)	1	1	2	1
Maturity date	7 Oct 85	18 Oct 85	4 Oct 85	11 Oct 85
Field duration (days)	83	94	74	81

†LP = land preparation, DAP = days after transplanting, PI = panicle initiation.

‡FP = farmers' practice, RP = recommended practice.

CLS		CHS		MPL	
FP	RP	FP	RP	FP	RP
IR36	IR64	IR42	IR42	IR42	IR42
2	2	2	2	1	2
2	2	2	2	2	2
80	45	80	45	150	45
37	37	38	38	30	30
8 Aug 85	8 Aug 85	8 Jul 85	8 Jul 85	15 Jul 85	15 Jul 85
random	0.20x0.20	random	0.20x0.20	random	0.20x0.20
84-0-0	60-0-0	61-0-0	60-0-0	50-6-12	57-6-12
-	40-0-0	-	40-0-0	-	14-6-12
84-0-0	-	61-0-0	-	14-6-12	23-0-0
-	20-0-0	-	20-0-0	36-0-0	20-0-0
0	2	1	2	1	2
0	1	1	1	0	1
27 Oct 85	2 Nov 85	23 Oct 85	23 Oct 85	5 Nov 85	5 Nov 85
80	86	107	107	113	113

requirement and at the same time they protected against yield loss. This helped them also in getting more return on their cash investment since their transplanting and weeding labor cost was relatively low.

To improve the investment return, in the 1986 wet season in the tested patterns, seed rates were increased, plant to plant spacings were reduced but all other practices remained unchanged. In the case of the farmers' practices, use of fertilizer increased except in the one simulated at IRRI. This was due to a lower cost of fertilizer in the market in 1986 (Table 6-4). As a result, there was no significant difference in grain yield except at SML (Table 6-2). At SML, too high a rate of N use caused the rice plants to be more vegetative in growth. This location was new in 1986-87 because of exclusion of MPL from the test program due to poor performance of legumes in the dry season and also due to some other management problems with the farmer cooperator. At IRRI, the 1985-86 field had to be changed due to a soil borne fungal problem which caused serious plant mortality in the legumes during the 1986 dry season. The poor performance of rice at IRRI during the 1986 wet season was due to poor water ponding and fertility of the new field.

For economic analysis the location at IRRI is excluded since the farmers' portion was not really farmer operated and for other locations two years of data were combined. Cost of different test factors for rice are presented in Table 6-5. Material cost needed in the recommended practices was lower than the farmers' practices at all locations mainly due to lower quantities of seed used. Fertilizer costs in the recommended practices were lower at CLS, CHS and

Table 6-4. Cultural and management practices used in rice crop of farmers' and tested cropping patterns grown with farmers' and recommended practices, respectively, at different test locations, 1986 wet season, IRRI, Philippines.

Cultural and management practices†	IRRI‡		BTG	
	FP	RP	FP	RP
Cultivar/line used	IR36	IR64	IR36	IR64
Plowings (no.)	2	2	1	1
Harrowings (no.)	2	2	2	2
Seeding rate (kg ha ⁻¹)	100	70	150	70
Seedlings age (days)	25	25	26	26
Transplanting date	8 July 86	8 July 86	22 July 86	22 July 86
Transplanting method (m x m)	random	0.15x0.20	random	0.15x0.20
N-P-K rate (kg ha ⁻¹)	45-9-17	60-0-0	63-14-0	60-9-0
During LP (kg ha ⁻¹)	-	30-0-0	-	30-9-0
10 to 20 DAT (kg ha ⁻¹)	20-9-17	-	25-14-0	-
2 to 5 DBPI (kg ha ⁻¹)	-	30-0-0	-	30-0-0
5 to 10 DAPI (kg ha ⁻¹)	25-0-0	-	38-0-0	-
Hand weeded (time/s)	0	1	1	1
Used insecticide (time/s)	1	1	1	1
Maturity date	7 Oct. 86	27 Oct. 86	19 Oct. 86	16 Oct. 86
Field duration (days)	92	112	90	87

†LP = land preparation; DAT = days after transplanting; DBPI = days before panicle initiation; DAPI = days after panicle initiation.

‡FP = farmers' practice; RP = recommended practice.

§30 DAT.

CLS		CHS		SML	
FP	RP	FP	RP	FP	RP
IR36	IR64	IR42	IR42	IR36	IR64
1	1	1	1	2	2
2	2	1	1	2	2
100	70	100	70	100	70
42	42	35	35	32	32
12 Aug. 86	12 Aug. 86	25 July 86	25 July 86	21 July 86	21 July 86
random	0.15x0.20	random	0.15x0.20	random	0.15x0.20
124-0-0	60-0-0	107-0-0	60-0-0	134-10-18	60-8-0
-	30-0-0	-	20-0-0	-	30-8-0
102-0-0	-	67-0-0§	20-0-0§	76-10-18	-
-	30-0-0	40-0-0	20-0-0	58-0-0	30-0-0
22-0-0	-	-	-	-	-
1	1	1	1	1	1
2	1	1	2	1	1
1 Nov. 86	2 Nov. 86	10 Nov. 86	10 Nov. 86	13 Oct. 86	17 Oct. 86
82	83	109	109	84	88

Table 6-5. Cost of test factors of rice of farmers' and tested cropping patterns grown with farmers' and recommended practices, respectively, at different test locations, IRRI, Philippines.

Test factors	BTG [†]		CLS	
	FP	RP	FP	RP
	\$ ha ⁻¹			
Material cost [‡]	89.0	68.9	81.8	54.0
Seeds	27.7	12.7	17.2	11.7
Fertilizer	43.1	48.4	56.6	30.1
Insecticide	18.2	7.8	8.0	12.2
Transplanting cost	18.6	70.0	23.9	51.8
Weeding cost	16.7	32.5	4.9	16.8

[†]Average of 1985 and 1986 wet seasons except SML and MPL which are for one season only; FP and RP = farmers' and recommended practices, respectively.

[‡]Includes interest - 4.9% annum⁻¹.

CHS		MPL		SML	
FP	RP	FP	RP	FP	RP
\$ ha ⁻¹					
90.0	62.7	83.1	73.5	96.6	64.4
17.7	11.2	38.0	11.4	19.4	13.6
36.5	29.3	45.1	51.1	71.5	35.1
35.8	22.2	-	11.0	5.7	15.7
20.8	43.5	11.7	56.1	24.2	46.1
4.3	77.0	44.0	40.1	5.9	20.0

SML but were slightly higher at BTG and MPL. Insecticide cost between the practices varied among the locations. Transplanting and weeding costs were consistently higher at all locations in the recommended practice compared to the farmers' practice.

According to cost and return analysis as presented in Table 6-6, gross returns from the recommended practice were higher at all locations compared to the farmers' practices. But net return was not so in all locations. It was lower in the recommended practice compared to the farmers practice at CHS mainly because of too high weeding cost particularly in the 1985 wet season. Weeding cost was dramatically reduced in the second year compared to the first year when transplanting was done at closer spacings. But transplanting cost could not be reduced since it took a lot of time to plant in rows in which farmers were not familiar. Net return per dollar in transplanting and weeding costs were higher in the case of the farmers' practices compared to the recommended practices. To make the recommended practices more profitable in all respects, some labor saving alternatives to the present recommended method of planting in rows must be worked out so that farmers would be able to transplant rice in rows.

Farmers' and recommended practices were compared in terms of dry fodder (straw) yield also. No significant difference was observed in any location except CLS where the recommended practice gave significantly higher dry fodder yield than the farmer's practice (Table 6-7). The dry fodder yield ranged from 3.0 to 6.10 Mg ha⁻¹ depending on cultivar, location and management practice used.

Table 6-6. Cost and return analysis of the rice crop of farmers' and tested cropping patterns grown with farmers' and recommended practices, respectively, at different test locations, IRRI, Philippines.

Test factors	BTG [†]		CLS	
	FP	RP	FP	RP
	\$ ha ⁻¹			
Gross return	548	703	586	636
Total variable cost (TVC)	270	306	289	306
Net return (NR)	278	397	297	330
NR per dollar investment (TVC)	1.05	1.30	1.03	1.08
NR per dollar material cost	4.12	6.76	4.63	7.11
NR per dollar transplanting cost	15.95	6.67	13.43	7.37
NR per dollar weeding cost	17.65	13.22	61.61	20.64

[†] Average of 1985 and 1986 wet seasons except for SML and MPL which are for one season only; FP and RP = farmers' and recommended practices, respectively.

CHS		MPL		SML	
FP	RP	FP	RP	FP	RP
$\$ \text{ ha}^{-1}$					
724	759	774	840	754	853
316	387	324	389	330	346
408	372	450	451	424	507
1.29	0.96	1.39	1.16	1.28	1.47
7.23	6.93	6.42	7.14	5.39	8.87
20.62	9.55	39.46	9.04	18.52	12.00
95.88	5.83	11.23	12.25	72.86	26.35

Table 6-7. Dry fodder yield of rice of farmers' and tested cropping patterns grown with farmers' and recommended practices, respectively, at different test locations, IRRI, Philippines.

Cropping patterns	IRRI	BTG	CLS	CHS	MPL	SML
	Mg ha ⁻¹					
Farmers	5.05 a [†]	3.00 a	3.59 b	4.50 a	6.10 a	5.10 a
Tested	6.00 a	3.20 a	4.05 a	4.60 a	6.00 a	4.90 a
cv (%)	11.40	4.16	1.30	3.46	1.32	3.72

[†]Average of 1985 and 1986 wet seasons except SML and MPL which are for one season only. In a column means having common letter are not significantly different at 0.05 level by Duncan's New Multiple Range Test.

Second Crop: Legume

Grain yield of the second crop/crop combination of the farmers and tested cropping patterns are presented in Table 6-8. Yields obtained in the 1986 dry season from different leguminous crops were low at IRRI and CHS, extremely low at BTG and CLS, and zero at MPL. But in the 1987 dry season, crop yields were extremely good at IRRI and CLS, reasonable at BTG and CHS and zero at SML. Apart from moisture stress, the other reason for poor performances that was common for all locations was fertilizer application during seeding. After harvest of the rice when furrows were opened among the rice stubble, many small weeds were present. There were also reasonable amounts of moisture at that time on the surface soil. When fertilizer was applied, those small weeds and the rice stubble grew vigorously making the crop seedlings unable to compete with them. As a result, hand weeding was required. This was time and cost consuming and was not very effective under zero tillage situations. As a result, the crop had poor growth and yield performance. In terms of net return also, the 1986 dry season was bad (Table 6-9). Production cost was too high owing to high labor requirements and high fertilizer and weeding costs. To ameliorate those common problems across the locations, in the 1987 dry season, new planting equipment was used which required less labor. Fertilizer was not applied, so little weeding was required. As a result, crop growth was not affected by intense competition with weeds and rice stubble. Grain yield and net return in general from all crop/crop combinations did improve.

Table 6-8. Grain yield of the second crop/crop combination of the farmers' and tested cropping patterns grown at different locations, 1986 and 1987 dry seasons, IRRI, Philippines.

Crop/crop combination†	IRRI		BTG		CLS		CHS	
	1986	1987	1986	1987	1986	1987	1986	1987
Mg ha ⁻¹								
Farmers':								
MB/fallow	-	-	-	-	-	0.8	0.2	0.4
Tested:								
CP	1.0	1.8	0	0.4	0.2	1.3	0.2	0
MB	0.1	1.5	0.1	0.3	0.1	0.5	0.5	0.3
PP	0.7	2.3	0.2	0.3	0.1	1.7	0.3	0.1
PP	0.5	1.6	0.2	0.3	0.2	1.0	0.2	0.2
+ CP	0.6	1.3	0.2	0.3	0.3	0.9	0.4	0
PP	0.8	2.4	0.2	0.2	0.2	1.5	0.2	0.2
+ MB	0.1	0.8	0.1	0.3	0.1	0.3	0.4	0.2

†MB = mungbean, CP = cowpea and PP = pigeonpea. No grain yield was obtained from any of the treatments at MPL and SML during 1986 and 1987 dry seasons, respectively.

Table 6-9. Net return of the second crop/crop combination of the farmers' and tested cropping patterns grown at different locations, 1986 and 1987 dry seasons, IRRI, Philippines.

Crop/crop combination†	IRRI		BTG		CLS		CHS		MPL		SML	
	86	87	86	87	86	87	86	87	86	87	86	87
\$ ha ⁻¹												
Farmers':												
MB/fallow	-	-	-	-	-	210	- 54	83	-	-	-	-
Tested:												
CP	264	958	-352	117	- 20	699	-196	- 98	-141	- 80	-	-
MB	-220	592	-313	83	- 25	108	-122	24	-121	- 70	-	-
PP	- 49	494	-313	- 98	-284	538	-210	-181	-136	- 90	-	-
PP + CP	127	1046	-333	- 5	-171	685	-132	-181	-165	-127	-	-
PP + MB	0	910	-367	1	-279	518	-230	- 88	-154	-116	-	-

†MB = mungbean, CP = cowpea, and PP = pigeonpea.

Because of poor performance of legumes in the 1986 dry season, no statistical analyses were attempted. Instead, the 1987 dry season data were used to run a cross location analysis of variance (Hildebrand and Poey, 1985). Since it is not appropriate to run any statistical analysis using grain yield data of different crops because of the differences in grain type, gross return data were used. Gross return was considered as the best and most widely acceptable substitute of all types of grains. Because of the presence of several zero values, data were transformed to $\log(x + 1)$ prior to analysis. Location by treatment interaction effect was significant at the 0.01 level (Table 6-10) meaning that performance of treatments varied from location to location. Comparing the main effect of either location over the mean of treatments or comparing the treatments over mean values of locations will have no statistical validity. So under this situation, for a clear understanding of treatment performances at different locations, modified stability analyses (Hildebrand, 1984) were done using gross return and net return values. In both of these cases, the average gross return of all treatments at each location formed the environmental index (e). Figure 6-7 (a) shows the performance of different treatments across the locations during the 1987 dry season in terms of gross returns which provides evidence that the test locations are part of at least two recommendation domains. It is difficult to indicate any exact boundary of the two recommendation domains since there is no cross-over of the regression lines. But based on the environmental index and performance of the treatments, it may be concluded that SML, CHS and BTG fell in the poor

Table 6-10. Analysis of variance of the gross revenue data of the 1987 dry season crops grown at different test locations, IRRI, Philippines.

Source	d.f.	MS	F	cv (%)
Location	4	125.00†	41.67 **	6.67
Block (location)	10	0.35	0.26 NS	
Treatments	4	3.32	1.11 NS	
Location * Treatments	16	3.00	33.33 **	
Error	40	0.09		

*,**Significant at 0.05 and 0.01 levels of probability, respectively.
NS = not significant.

†Data were transformed to $\text{Log}(x + 1)$.

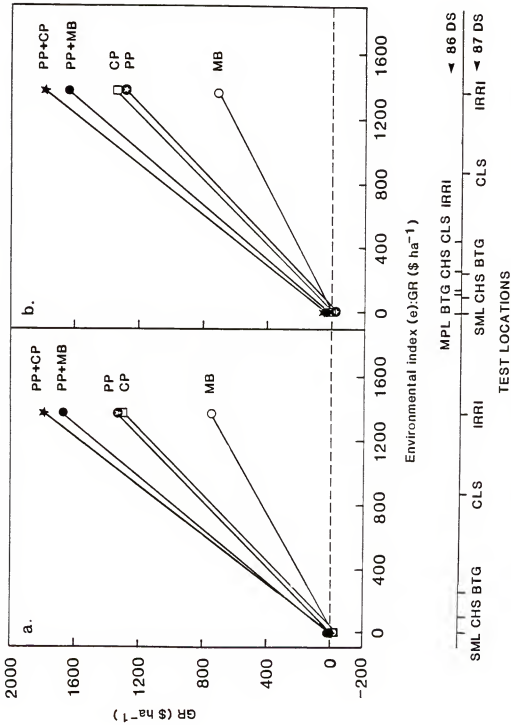


Fig. 6-7. Performances of different crop/crop combinations across the test locations in terms of gross return (GR) using modified stability analysis. (a) 1987 dry season (DS) data alone, (b) 1986 and 1987 DS data combined.

environments whereas CLS and IRRI were on the better environments. In the better environments, PP + CP gave the highest gross return followed by PP + MB. Sole cropping of mungbean gave the lowest gross return compared to all other treatments at all environments. Figure 6-7 (b) shows the performance of different treatments when 1986 and 1987 gross return data were combined. The overall performance of the treatments was not good during 1986 which can be understood by looking to the positions of the test locations in terms of the environmental index. As a result, the data points of the different treatments during 1986 moved to the left but their combining with 1987 data did not change the treatments' overall relationship compared to that of 1987 data alone. This indicates that for the modified stability analysis, one season data is not meaningless but two season's data give more strength to it.

When the treatments were compared in terms of net returns, the differences became more meaningful and the performances changed across the locations. In 1987 in the better environment at IRRI, PP + CP gave the highest net return but at CLS, it performed equally with cowpea alone, whereas at the poor environments of SML and CHS, it gave the highest negative net return (Fig. 6-8a). Intercropping costs more money in terms of more seeds, insecticides and labor. If it does not produce sufficiently more than the sole crop, then it would be always losing. This is what happened in case of the intercrop treatments at the poor environments. The net return from the sole crops was also negative in the poor environments of SML, CHS and BTG meaning that production of none of the legumes tested as either sole or in

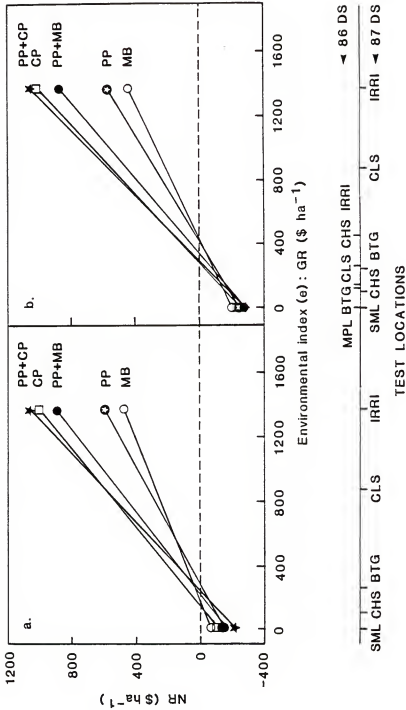


Fig. 6-8. Performances of different crop/crop combinations across the test locations in terms of net return (NR) using modified stability analysis. (a) 1987 dry season (DS) data alone, (b) 1986 and 1987 DS data combined.

intercrop combination would be profitable in the poor environments. At better environments, production of all the treatments was profitable. In the poor environments, gross return of \$200 to 400 ha^{-1} was necessary for production of any of the legumes tested to avoid financial loss. When the net return data of 1986 were combined with 1987, the trend in performance of treatments changed little except that a gross return of \$300 to slightly over \$400 ha^{-1} was necessary to break even with any of the legumes tested (Fig. 6-8b). This means that recommendations for production of the tested legumes should not be made in those locations where $e < 400$. However, in terms of net returns, the treatments that performed quite well in the two better environments, IRRI and CLS, were PP + CP, PP + MB, and cowpea alone.

During the dry season, labor availability is no problem. Usually in rainfed agriculture this is the slack time of the year when the farm family is relatively more free to do any farm activity that might bring some profit to them. The most limiting factor during that time of the year is soil moisture. Farmers usually try to grow whatever they can by utilizing their free family labor and the scarce resources as long as the activity does not cause any cash loss and serves the farm family's needs in one way or another. Based on this understanding, the treatment performances across the locations were also evaluated in terms of net returns considering the cash expenses only (Fig. 6-9). By this economic measure, profitability improved further compared to net returns based on total variable costs. The ranking of the three best performing treatments changed considerably.

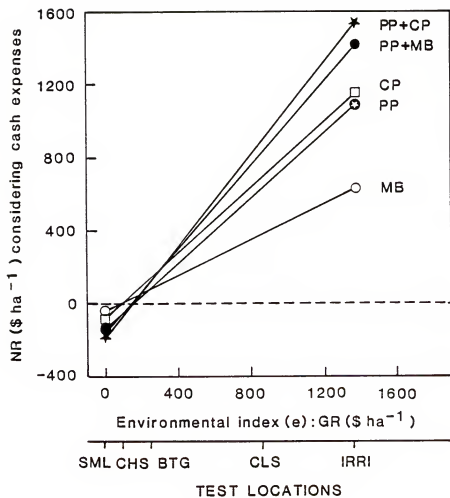


Fig. 6-9. Performances of different crop/crop combinations across the test locations in terms of net return (NR) considering cash expenses only during 1987 dry season using modified stability analysis.

The PP + MB treatment became the second best instead of cowpea alone which was due to its higher gross return. The regression equations and the coefficients of determination of the performances of different treatments shown in Figs. 6-7 through 6-9 are presented in Table A-1 in the appendix.

For more critical evaluation of the three well-performing treatments the distribution of confidence intervals (Hildebrand, 1984) were made using net returns. First, data from all the five locations of 1987 dry season were analyzed. Figures 6-10 and 6-11 show the performances of the treatments in terms of net return considering the total variable costs, and net return considering cash expenses, respectively. The performance of the treatments in the latter case was slightly better than the net return considering the total variable costs, but farmers will lose money at least one out of every four seasons irrespective of the treatments they adopt. But at the same time there was a chance of getting very good net return also. However, there were not many differences among the three treatments in terms of confidence intervals. The performance of the treatments became poor here because of the inclusion of the three poorer environments in the analysis.

When analyses were done only with the better environments of CLS and IRR1, where average net return was positive, the performances changed dramatically. In terms of net return considering both labor and material costs, PP + CP was the best treatment though sole cowpea exhibited more stability (Fig. 6-12). Average net return from PP + CP treatment was \$867 ha⁻¹ followed by cowpea alone which had \$829 ha⁻¹.

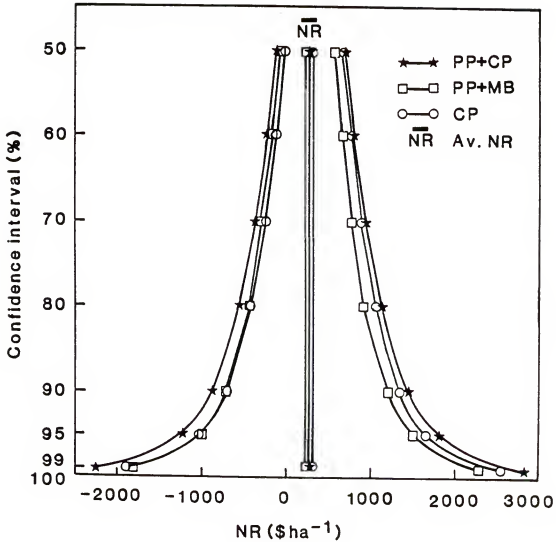


Fig. 6-10. Distribution of confidence intervals, for net return (NR) of three best performing crop/crop combinations across all the test locations during 1987 dry season.

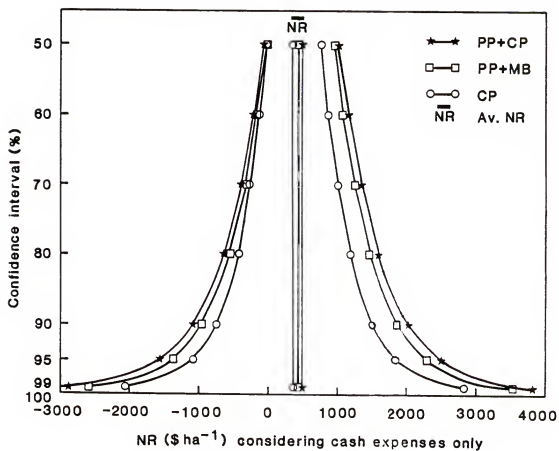


Fig. 6-11. Distribution of confidence intervals for net return (NR) considering cash expenses only of three best performing crop/crop combinations across all the test locations during 1987 dry season.

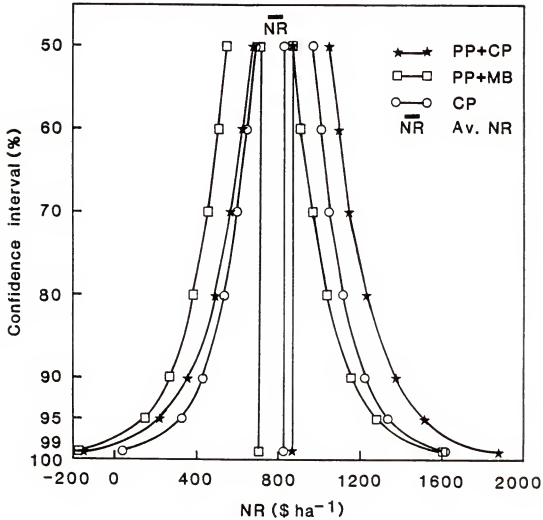


Fig. 6-12. Distribution of confidence intervals for net return (NR) of three best performing crop/crop combinations across two best locations (IRRI and CLS) during 1987 dry season.

Even with 95% confidence there were no chances of getting any negative returns from any of the three treatments. In terms of net return considering the cash cost only as expenses, the overall return increased further and PP + MB became the second best though cowpea alone still maintained its best stability (Fig. 6-13).

In terms of both modified stability analysis and confidence interval study, the PP + CP treatment was the best in the better environments.

Apart from monetary evaluation, the treatments were also evaluated in terms of dry fodder yield. Fodder did not have any price in the market during the period of experimentation and also was not sold anywhere in the country. Farmers also did not care much about the fodder yield and for its safe preservation but the present Government and research thrust in the country is to increase the production of fodder at all possible levels so that the animal sector can be improved.

Data obtained on dry fodder yield are presented in Table 6-11. Except at IRRI, at all other locations cowpea and mungbean did not differ in terms of fodder yield, and the yields were low. The treatments that gave higher fodder yields at all locations were either sole pigeonpea or pigeonpea intercropped with cowpea or mungbean, because those pigeonpeas were ratooned and left in the field to regrow after their grain was harvested and subsequently harvested again at the end of June by which time there was a lot of vegetation growth due to the onset of the monsoon. Hence, in poor environments, like BTG and CHS, grain yield of pigeonpea in sole or in intercrop combination

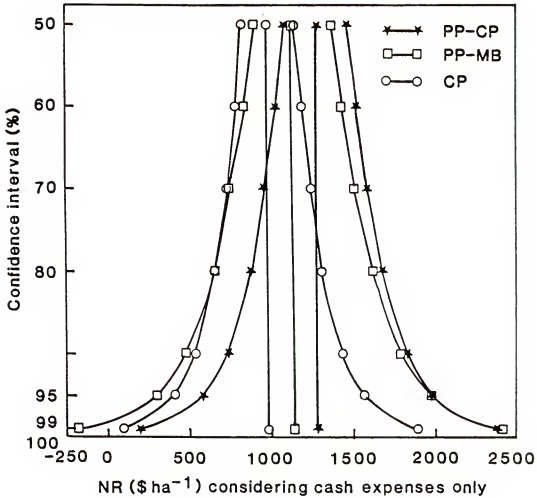


Fig. 6-13. Distribution of confidence intervals for net return (NR) considering cash expenses only of three best performing crop/crop combinations across two best locations (IRRI and CLS) during 1987 dry season.

Table 6-11. Dry fodder yield of the second crop/crop combination of the farmers' and tested cropping patterns grown at different locations, 1986 and 1987 dry seasons, IRRI, Philippines.

Crop/crop combination†	IRRI		BTG		CLS		CHS	
	1986	1987	1986	1987	1986	1987	1986	1987
Mg ha ⁻¹								
Farmers':								
MB/fallow	-	-	-	-	-	0.3 c	-	0.5 b
Tested:								
CP	1.4 c‡	2.4 b	0.2 b	0.8 b	0.1 d	0.9 c	0.2 c	0.2 b
MB	0.0 d	0.4 c	0.1 b	0.2 b	0.1 d	0.4 c	0.1 c	0.2 b
PP	1.9 b	2.8 ab	1.7 a	5.2 a	1.1 c	5.0 a	1.5 b	2.1 a
PP + CP	2.9 a	3.2 a	1.8 a	3.7 a	2.0 b	4.1 b	1.8 a	2.1 a
PP + MB	2.0 b	3.2 a	1.8 a	3.5 a	2.5 a	4.6 ab	1.9 a	2.2 a
cv (%)	9.6	16.4	23.8	37.6	16.0	15.9	11.7	18.1

†MB = mungbean, CP = cowpea, and PP = pigeonpea.

‡For a column, means having common letter/s are not significantly different at 0.05 level by Duncan's New Multiple Range Test.

was not very encouraging but fodder yield was good. This means that if fodder gets any monetary value over time then in those locations, treatments involving pigeonpea will surely get better preference than now and may be considered for farmers' adoption. So, pigeonpea as a dry season crop following lowland rice may have potential in poor environments not for grain yield but for fodder yield.

In addition to the management problems mentioned earlier which were responsible for the overall poor grain and economic productivity of the 1986 dry season crop, there were also some other reasons and observations, which would explain the location to location and year to year variation of crop performance. These will be discussed by location.

At IRRI, the field used for this trial in 1986 had soil problems which favored high seedling mortality at the beginning of the dry season. Reseeding was done to maintain the desired plant population. Crop growth was not good from the late emerged plants probably due to moisture stress. Otherwise, the performance at IRRI would have been much better during 1986 dry season. In 1986, pigeonpea at IRRI did not produce any grain yield from the ratoon crop but in 1987, it produced an all treatment average yield of 0.84 Mg ha^{-1} . This was possibly due to better soil moisture (Fig. 6-14), higher air temperature (Fig. 6-2), and lower relative humidity (Fig. 6-3) compared to the 1986 dry season.

At BTG, soil moisture was better in the 1987 dry season (Fig. 6-14) compared to the 1986 dry season. The overall yield should have been much better than what happened (Table 6-8). It did not improve

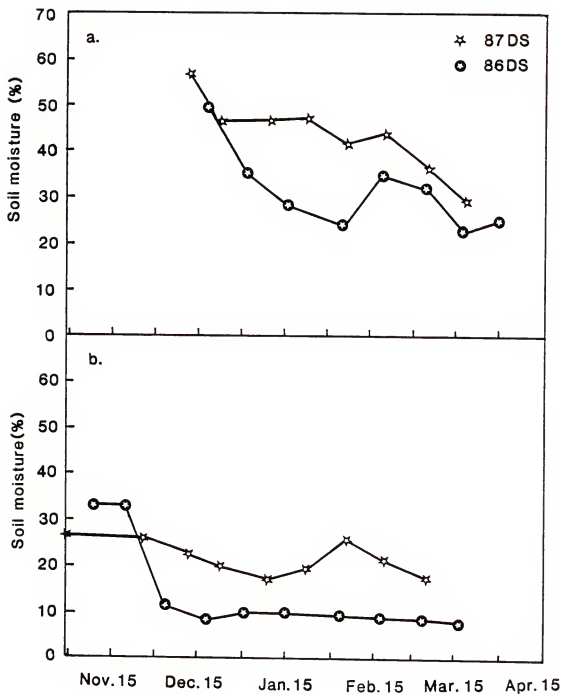


Fig. 6-14. Soil moisture content at different test locations at 0.30 m depth as determined by gravimetric method approximately at two weeks interval during 1986 and 1987 dry seasons (DS). (a) IRRI, and (b) BTG.

much because of flooding of the field for more than 24 hours at the seedling stage due to heavy rain caused by a typhoon. This is a risk factor that existed over all locations and will continue to be for the researchers and prospective farmers. A sudden rise in the soil moisture curve in 1987 at BTG (Fig. 6-14) during January was not due to rain. Rather it was due to seepage of water from a nearby field in which another farmer transplanted rice with water from his shallow tube-well. This is a type of problem that might develop anywhere in farmers' fields. At BTG, pigeonpea flowered during 1987 but did not set any pods in the main crop. It was possibly due to a too high temperature (Fig. 6-5) and drier environment. But surprisingly, the same crop after ratooning produced an all treatment average grain yield of 0.24 Mg ha^{-1} .

At CLS, better performance of dry season crops during 1987 compared to 1986 (Table 6-8) were due to better soil moisture in 1987 (Fig. 6-15) and also one good shower after emergence of seedlings enabled them to get a good start. To be able to complete seeding at the right time is a big factor in the success of the dry season crop.

At CHS, performance in 1986 was better than 1987. It was expected to do much better in 1987 than 1986 because of the improvement of the management technologies. Failure in 1987 was due to a typhoon following seeding. When the seedlings were emerging, the surface soils were over saturated for 2 to 3 days resulting in seedling death. To reseed the trial took another week. By that time the moisture level at deeper levels of the soil profile was reduced. So when the seedlings emerged they did not have enough moisture from

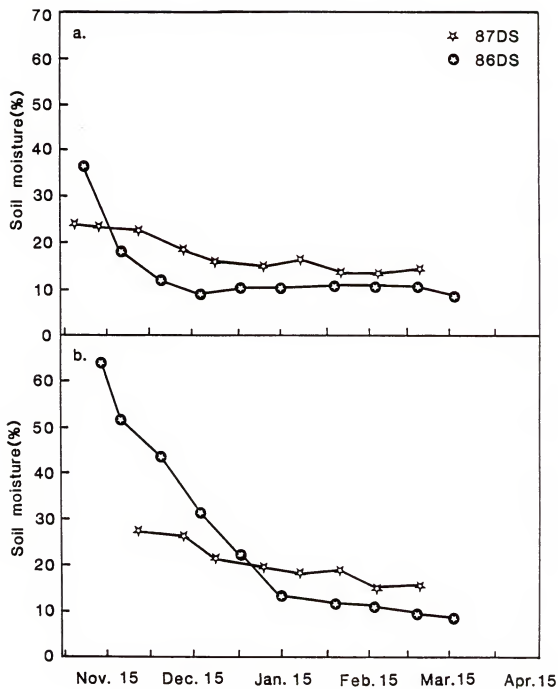


Fig. 6-15. Soil moisture content at different test locations at 0.30 m depth as determined by gravimetric method approximately at two weeks interval during 1986 and 1987 dry seasons (DS). (a) CLS, and (b) CHS.

the deeper layer. Also those were not so developed to spread their roots deeper. As a result growth was not satisfactory. Compared to this in 1986, seedlings emerged at the right time when there was enough moisture (Fig. 6-15). Seedlings developed fast and before the surface soil dried up those were able to spread their root system. As a result, even though the late season soil moisture was low in 1986 the performance of the crops was better.

At CLS and CHS, farmers usually grow mungbean in the dry season on a small scale. Their traditional way is to plow the field with mouldboard plow once after harvest of rice and then broadcast the mungbean seeds and finally harrow to cover up the seed. This practice was observed to be better than the zero tillage technique which is also evidenced by the performance of farmers' mungbean compared to tested mungbean during 1987 at CLS and CHS (Tables 6-8 and 6-9). The reason was, in the farmers' practice, because of disturbing the soil, weeds and the rice stubble were killed and the newly emerged seedling were more vigorous and able to penetrate the subsoil before the surface soil dried. As a result, initial growth was better under farmers' practices compared to zero tillage where initial growth was slow. Better initial growth means faster root development, and better and deeper anchorage which ultimately pays when the moisture stress starts increasing with the progress of the season.

So, it seemed from the observation and the findings that zero tillage would be good only where there would be no moisture stress as at IRRI. But at places with moisture stress, minimum tillage would do better than zero tillage. Further research and observation along this line would clarify the situation better.

At MPL, soil moisture was not the problem (Fig. 6-16) at least for the initial period. Seedlings emerged at the right time, but did not grow after that. Mungbean and cowpea survived up to a month and then gradually died out, whereas pigeonpea continued to remain in the field up to flowering but did not grow more than 0.10 to 0.20 m in height and then ultimately died out. The soil pH was 4.9 due to which the availability of phosphorus (Olsen) was also low (1.4 ppm). Possibly this was the major reason why none of the crops grew well here. There were some operational problems also at this location with the farmer cooperator. Hence, this location was abandoned and SML was opened for the 1986-87 season.

At SML, the soil pH was 5.5 and the availability of phosphorus (Olsen) was also better (11.0 ppm). The soil moisture condition was not bad (Fig. 6-16). But the performance of the crops was the same as for MPL. Soil acidity may have had something to do with crop production under zero tillage in a moisture limiting situation. This needs to be further investigated.

Figure 6-17 shows the soil moisture contents at 0.30 m depth of different test locations for both the 1986 and 1987 dry seasons. In both years the soil moisture at IRRI during the entire season was better than all other test locations which was one of the major reasons why performance of legumes was better at IRRI in both years. Moisture at MPL and SML during the 1986 and 1987 dry seasons, respectively, was reasonably good compared to other test locations, still none of the tested legumes grew well. This signifies that moisture probably was not the most limiting factor in those two test

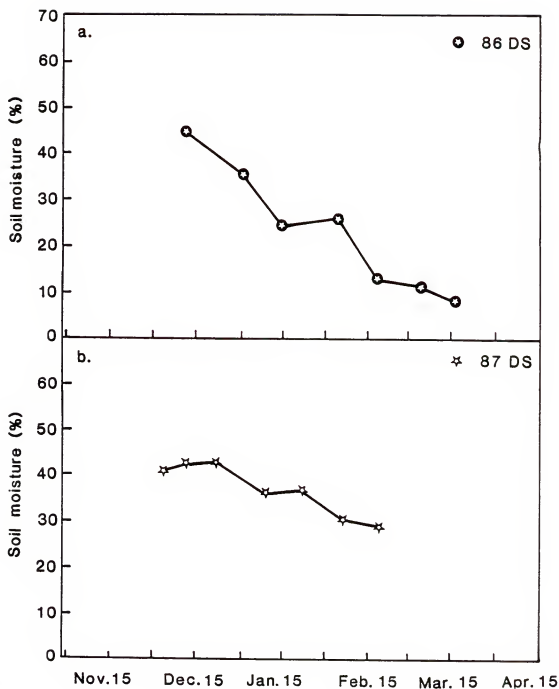


Fig. 6-16. Soil moisture content at different test locations at 0.30 m depth as determined by gravimetric method approximately at two weeks interval during 1986 and 1987 dry seasons (DS). (a) MPL, and (b) SML.

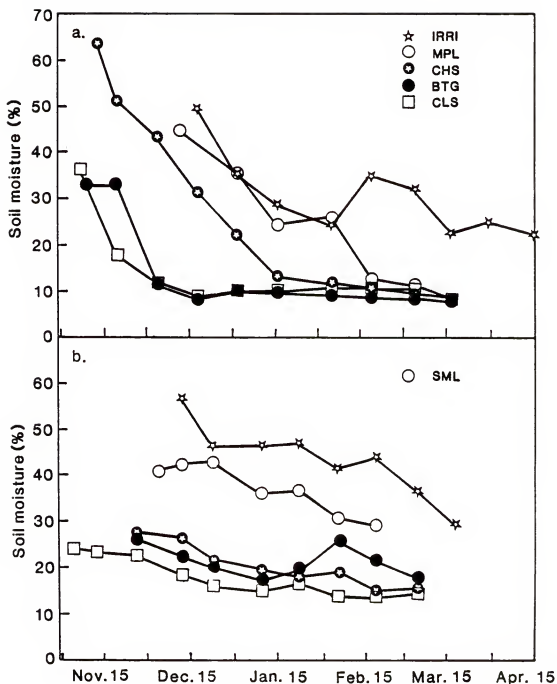


Fig. 6-17. Soil moisture content at different test locations at 0.30 m depth as determined by gravimetric method approximately at two weeks interval. (a) 1986 dry season (DS), and (b) 1987 DS.

locations. In general, soil moisture conditions during the 1987 dry season was slightly better than the 1986 dry season.

Cropping Pattern: Rice Followed by Legume/Fallow

Net return of the farmers' and tested cropping patterns grown at different locations during 1986-87 seasons are presented in Table 6-12. At IRRI and CLS, all the tested patterns were better than farmers' patterns but economic productivity of the tested patterns varied at both the places. Among sole crops, cowpea performance was best both at IRRI and CLS. Among intercrops, PP + CP was on the top. At CLS, cowpea solecrop was marginally better than PP + CP. Farmers, during their field visit at CLS, indicated their preference towards sole cowpea rather than PP + CP due to its simplicity in seeding and less input requirement compared to any of the intercrop combinations though they were told about the potentials of higher grain and fodder yield from the intercrop combinations. At BTG, except for rice followed by pigeonpea, all tested patterns gave higher net return than the farmers' rice-fallow pattern. Rice-cowpea was the best. At CHS, none of the tested patterns did better than the farmer's rice-mungbean. At MPL and SML, since none of the legume crops or crop combinations did grow, it is clearly understood that farmers' pattern-rice-fallow, was the best.

Dry fodder yield of the farmers' and other tested patterns are given in Table 6-13. At IRRI, all the tested patterns except R-MB were statistically similar and were better than the farmers' simulated R-fallow pattern. At BTG, the highest fodder yield was from R-PP. At

Table 6-12. Net return of the farmers' and tested cropping patterns grown at different locations during 1986 and 1987 seasons, IRRI, Philippines.

Cropping patterns†	IRRI			BTG			CLS			CHS		
	1st crop	2nd crop	Total	1st crop	2nd crop	Total	1st crop	2nd crop	Total	1st crop	2nd crop	Total
\$ ha ⁻¹												
Farmers':												
R-MB/												
fallow	237	-	237	321	-	321	244	210	454	417	1703	2120
Tested:												
R-CP	240	958	1198	381	117	498	402	699	1101	456	-2029	-1573
R-MB	232	592	824	364	83	447	418	108	526	460	490	950
R-PP	253	494	747	381	- 98	283	423	538	961	452	-3074	-2622
R-PP+CP	240	1046	1286	383	- 5	378	413	685	1098	441	-3692	-3251
R-PP+MB	258	910	1168	361	1	362	420	518	938	465	-1769	-1304

† R = rice, MB = mungbean, CP = cowpea, and PP = pigeonpea.

CLS and CHS also, the highest fodder yield was from the tested patterns having pigeonpea either as solecrop or in intercrop combinations.

Based on both net return and dry fodder yields of farmers' and tested cropping patterns at all test locations, it may be concluded that at better environments, such as at IRRI and CLS, any of the test patterns would do better than the farmers. But which one to grow will depend on the individual's likings and requirements. At moderately poor environments, such as BTG and CHS, a certain risk is involved in making any recommendation of the tested cropping patterns for economic profitability without further study. In the poorest environments, such as MPL and SML, farmers' R-fallow is still the best recommendation.

Farmers' Perceptions About the Entire Process

In testing a technology in farmers' fields, researchers' or observers' priorities are useful, but for adoption of technology by farmers, the farmers' perceptions and priorities are very important. A technology may be very productive from the researchers' points of view but unless the farmers who are the ultimate clients adopt that technology because of their own reasons, the technology will have little value. So, it is always important and necessary to try to understand the farmers' perceptions and priorities in any attempt to improve farmers' condition. This also helps in identifying other factors that researchers perhaps have not considered before.

Table 6-13. Dry fodder yield of the farmers' and tested cropping patterns grown at different locations during 1986-87 seasons, IRRI, Philippines.

Cropping patterns†	IRRI	BTG	CLS	CHS
	Mg ha ⁻¹			
Farmers':				
R-MB/fallow	7.0 b [‡]	3.6 c	3.6 c	5.4 b
Tested:				
R-CP	10.8 a	4.1 c	5.3 b	5.8 b
R-MB	8.8 b	4.0 c	4.6 b	5.8 b
R-PP	11.6 a	8.7 a	9.3 a	7.8 a
R-PP+CP	11.4 a	7.1 b	8.6 a	8.1 a
R-PP+MB	11.6 a	7.1 b	9.1 a	7.9 a
cv (%)	10.0	12.0	8.8	6.1

†R = rice, MB = mungbean, CP = cowpea, and PP = pigeonpea.

‡Means in a column having common letter are not significantly different at 0.05 level by Duncan's New Multiple Range Test.

At all test locations, one thing that was common and must be appreciated at the beginning was the farmers' cooperation in all possible respects to facilitate the research activities. This not only indicated that, though they were not highly placed in the human society in terms of their class categorization compared to generally well educated and richer urban people, yet they have exhibited a good deal of respect and importance for others' work. They were not able to understand the exact reasons for many of the research activities conducted in the field. But at least they understood that the efforts were for the well being of the entire agricultural community. As a result, there were no physical barriers or trouble in carrying out the day to day research operations. Crops were not damaged by any individuals. During the dry season, animals that were grazing around were kept a reasonable distance from the test field to avoid destruction of the research materials. Farmers provided help whenever needed in terms of labor and other material resources; though not free, without those at least some operations would have been difficult to carry out. All this means that the farmers understood the need for improvement of their farming, and they cared for it.

Regarding the scientific aspect, farmers were very vigilant about what was happening in the test fields. They did not visit the test fields very often in a group but it was noticed and understood that each and every farmer one way or other passed by and evaluated the test fields. By discussing with farmers at all locations and by trying to understand from their activities and behavior, it is understood that farmers liked rice cv. IR 64 instead of their cv. IR

36. Farmers said this was mainly due to higher grain yield and better panicle size of IR 64.

When farmers transplant rice, they do not like to plant it in rows due to the high labor requirement, and labor was very scarce during the peak time of transplanting. Weeds in rice fields, particularly around 3 to 6 weeks after transplanting did not seem like any problem at all to the farmers. If weeds grew too much and showed up prominently during early flowering time of rice, only then did the farmers do some spot weeding. Otherwise they did not want to do any weed control in transplant rice. It seemed as if farmers did not like the hand weeding operation very much. They in fact use a high plant density, which controls the weeds to a very good extent in most cases unless there is a shortage of ponded water in the field. Farmers prefer a high density because of its higher production per unit area, but the density also functions to partially control weeds.

During the dry season, the farmers observed the technique of seeding legumes in rows under zero tillage for both sole and intercrop. The first year planting technique was not liked by the farmers because it required too much labor. They liked the second year's planting equipment (inverted T-seeder), but preferred to have some equipment that can be pulled by their bullock or water buffalo instead of by a hand tractor. This was mainly because of cost considerations, simplicity and availability of animals at the farm level.

Among the three different legumes tested, farmers preferred cowpea, mainly because the crop grew well, grain yield was good, and

the market price was high compared to mungbean and pigeonpea. Cowpea is a good fodder crop, but apparently it seemed that farmers had not considered that point at all. Fodder was not at all an issue for consideration to them because they did not realize the need of that for their animals' health. They did not like pigeonpea much, mainly because the crop was new to them, though it gave a high fodder yield. Moreover, animals did not eat much pigeonpea fodder, particularly when other feeds were available. Farmers even mentioned that their cattle and carabaos (water buffaloes) did not like pigeonpea plants. Farmers also noticed that pigeonpea needed too much insecticide spray to save the crop from heavy insect infestation, which they also considered a negative factor for pigeonpea.

The farmers appreciated the performance of intercropping pigeonpea with mungbean and cowpea at CLS, but when asked which crop or crops they will grow next time in their field, most of them answered sole cowpea. This was probably because intercropping was not common in the locality and the advantages of staggered harvesting of grain, as well as fodder were not well perceived by the farmers. The complexity of seeding and more cost involvement in intercropping were other negative factors.

The farmers did not like the zero tillage technique very much. They observed that mungbean grew better in farmers' fields with minimum tillage (the farmers' method of one plowing followed by broadcast seeding and subsequent harrowing) compared to the other mungbean planted in the test plots with zero tillage.

The farmers were also aware of the risk of having a typhoon during establishment of a dry season crop. Hence, considering all the factors discussed above, it seems that in the near future most of the farmers will go for IR 64 instead of IR 36 (provided the seeds are available), but only a few may try sole cowpea during the dry season with their own management, if they want to try a dry season crop at all. Otherwise, they will wait to get more information before they attempt anything new.

Conclusions

In rice production during the first year, the recommended practice gave higher or equal grain yield than farmers' practices but not higher return to investment due to high labor cost for transplanting in rows and use of wide spacings resulting in higher weed control cost. In the second year, plant spacings were reduced which increased the grain yield further and improved the economic profitability of the recommended practice over farmers' practices but still net return per dollar transplanting and weeding costs were higher in the farmers' practices. Farmers were not interested in planting in rows because of the high labor requirement which was very scarce at peak planting time in their rainfed agriculture. Some alternative to this problem should be evolved if row planting is to be made adaptable to the farmers.

Performance of legumes either alone or in intercrop combinations under zero tillage residual soil moisture conditions following lowland rice was not good in most of the locations tested during the first

year because of a fertilizer application which favored weed growth and initiated regrowth of the rice stubble. Use of hand a tractor with drag stick for opening furrows and hand seeding was also economically unproductive because of a high labor requirement. Use of an inverted T-seeder in the second year was effective for good seedling establishment, time saving and economic productivity. No use of fertilizer and better planting equipment improved the overall performance of the legumes across the locations during the 1987 dry season.

Statistical analysis, using gross return values, as a substitute for grain yield of different legumes, as sole or in intercrop combinations, indicated highly significant interaction between location and treatment. Production of legumes either alone or in intercrop combinations was found to be economically profitable only at the better environments such as IRRI and CLS where soil pH was near neutral and the moisture condition was favorable for crop growth. Distribution of confidence intervals indicated a profit with at least 95% confidence. The PP + CP treatment was the best both in terms of modified stability analysis and confidence intervals in the better environments.

In the moderately poor environments, though grain yield was not good enough to economically justify the production of any legumes, fodder yield of pigeonpea in those areas indicated good promise for the future when fodder will have economic values in the market or to the farmers. These environments were characterized by increased moisture stress as compared with the better environments. In the

poorest environments, legumes in the dry season would not be profitable. The poorest environments were characterized by very low soil pH.

Occasional prolonged rain due to typhoon was described as serious threat or risk for the successful establishment of dry season crops particularly in the Philippines. The farmers' practice of growing mungbean by plowing the field followed by broadcasting the seeds and subsequent harrowing was found to give better crop growth, higher grain yield and economic productivity compared to zero tillage planting of mungbean particularly under moisture stress situations. But mungbean or cowpea planted with zero tillage with little moisture stress exhibited excellent performance in other places. This indicated the need of further study along the line. Further study is also suggested on production of legumes under zero tillage residual soil moisture conditions following lowland rice in acid soils.

CHAPTER VII SUMMARY AND CONCLUSIONS

Rainfed lowland is one of the most important crop production areas in the Philippines and also in other Asian countries where in most cases after the production of the main rice crop, the land remains idle due to progressive depletion of soil moisture. With an objective to increase the productivity of this agro-climatic situation by incorporating short duration, drought tolerant, dual-purpose pigeonpea, four different experiments were conducted for two years in the Philippines.

Experiment 1: Growth and Yield of Short Duration Post-Rainy Season Pigeonpea as Affected by Different Plant Spacings and Densities

Lack of sufficient information on the best combination of row spacing and plant density for maximum productivity under this situation necessitated this study in which two field experiments were conducted in two years with varied levels of row spacings and plant densities under zero tillage at IRRI, Philippines. Results indicated that short duration post-rainy season pigeonpea can be grown successfully under zero tillage conditions in rainfed lowland following rice. The interaction effect of row spacing and plant density was significant on light interception, LAI, and phytomass yield at maximum vegetative growth stage but not on main crop grain yield, which was more affected by row spacing than plant density.

Closest row spacing gave significantly better main crop grain yield than other treatments having wider row spacings. The best treatment in terms of main crop grain yield, light interception, LAI, and phytomass production at maximum vegetative growth stage was 0.30 m row spacing with 50 plants m^{-2} . Ratoon crop grain yield, and fodder and firewood yields were not affected by row spacings and plant densities.

Experiment 2: Intercropping Short Duration Post-Rainy Season
Pigeonpea with Mungbean and Cowpea

This study was done in upland with full tillage and fertilizer where pigeonpeas were intercropped with mungbean and cowpea at two levels of each intercrop density (D) and row arrangement (R) using a randomized complete block design for two years at IRRI, Philippines. The objectives were to determine the productivity and best intercrop combination of mungbean and cowpea with pigeonpea.

Based on LAI, light interception, and dry phytomass at 6 WAE, it may be concluded that in 1986, intercropping of mungbean and cowpea with pigeonpea was advantageous. As an intercrop cowpea was better than mungbean. In the case of both mungbean and cowpea, best intercrop treatment was 100% D with 1:2 R. In 1987, intercropping was not advantageous. Contribution of mungbean in the intercrop output was insignificant probably due to higher density of pigeonpea. In the case of cowpea, the reverse happened--pigeonpea was suppressed. This was possibly because of better fertility and less weed growth in the field during 1987. In terms of grain yield, the same trend was observed. Mungbean was affected by pigeonpea while pigeonpea was affected by cowpea. So, there was no grain yield advantage for

intercropping pigeonpea with mungbean. In the case of cowpea, however, in 1986, 100% D with 1:2 R showed grain yield advantage over other treatments. A LER value of 1.67 was also obtained from the same PP + CP combination in 1986 but in 1987, LER values were not very high from any of the combinations tested.

In terms of both fresh and dry fodder yield, sole crops differed significantly in both years; intercrop combinations differed only in 1987 but not in 1986. Highest actual fodder yield was from PP + CP with 100% D and 1:2 R. The same treatment was better in 1986 based on net return whereas sole cowpea was the best in 1987.

Mungbean may not be used for intercropping with pigeonpea under rainfed upland situations. Cowpea, if used, must be done under lower fertility and moisture situations in 100% D with 1:2 R for maximum productivity. At higher moisture and fertility levels, cowpea will suppress the pigeonpea growth and in that case sole cowpea would do better than intercropping.

Experiment 3: Productivity and Methods of Ratooning Short Duration Post-Rainy Season Pigeonpea

Ratooning is one of the means to increase agronomic productivity of perennial crops. With the objective to determine its effectivity and applicability in post-rainy season pigeonpea following lowland rainfed rice, the present study using three different cutting heights and one control treatment was conducted for two years at IRRI, Philippines.

Results indicated that productivity of the ratoon crop of short duration post-rainy season pigeonpea following lowland rainfed rice

depended mainly on the soil moisture conditions that existed after the first harvest of grain or ratooning. If the soil moisture remained favorable (at least 30 to 35% moisture at 0.30 m depth in clay soil) then plants will probably flower and produce a second set of grain, otherwise they will continue to maintain slow growth until the rain starts. Ratooning delayed the flowering and pod bearing because of required vegetative regrowth, hence, under favorable soil moisture conditions, leaving the plants without ratooning after hand picking of the main crop pods is recommended for higher second harvest grain yield. Ratooning did not cause any significant plant mortality. Hence, when only fodder and firewood yields are expected then 40 or 60% canopy cut would be better in terms of ratooning time compared to zero or 20% cut.

Under favorable soil moisture conditions, a total of 2.9 Mg ha^{-1} grain yield was possible by two harvests from the plants having no cut. The second harvest of grain was slightly higher than the first harvest. All treatments and two season average dry fodder and firewood yields were 2.5 Mg ha^{-1} for each.

Experiment 4: Comparison of Different Cropping Patterns on Rainfed Lowland Areas of the Philippines

With an objective to determine the best cropping pattern and also to observe the comparative performance of pigeonpea, five different cropping patterns involving three different legumes either as sole or in intercrop combinations in a zero tillage residual soil moisture condition following lowland rainfed rice were compared with the farmers' cropping patterns for two years across five locations in

farmers' fields and one location at IRRI, Philippines. The farmers' patterns were managed by the farmers with the farmers' own practices and tested patterns were managed by researchers with recommended practices.

In rice production during the first year, recommended practices gave higher or equal grain yield than farmers' practices but not higher return to investment owing to high labor cost for transplanting in rows and use of wider row and plant spacings resulting in higher weed control cost. In the second year, plant spacings were reduced which increased the grain yield and improved the economic profitability of the recommended practice over farmers' practices but still net return per dollar transplanting and weeding costs were higher in the farmers' practices. Farmers were not interested in row planting because of the high labor requirement which was very scarce at peak planting time in their rainfed agriculture. So some alternative to this problem should be evolved if row planting is to be made adaptable to the farmers.

Performance of legumes, either alone or in intercrop combinations under zero tillage residual soil moisture conditions following lowland rice, was not good in most of the locations tested during the first year because of fertilizer application which favored weed growth and initiated regrowth of the rice stubble. Use of a hand tractor with drag stick for opening furrows and hand seeding was also economically unproductive because of the high labor requirement. Use of an inverted T-seeder in the second year was effective in terms of good seedling establishment, time saving and economic productivity. No use

of fertilizer and better planting equipment improved the overall performance of the legumes across the locations during the 1987 dry season. Statistical analysis using gross return values as a substitute for grain yield of different legumes as sole or in intercrop combination indicated highly significant interaction between location and treatment. Modified stability analysis using gross and net return values indicated at least two recommendation domains. Production of legumes either alone or in an intercrop combination was found to be economically profitable only in the more productive environments during the 1987 dry season. Distribution of confidence intervals using net return data of the three best performing treatments over all five test locations indicated negative return at least in one out of four years. But in the more productive environments (two good locations), the risk factor disappeared dramatically indicating a good profit with at least 95% confidence. The PP + CP treatment was the best both in terms of modified stability analysis and confidence intervals in the better environments. In the poor environments, grain yield was not enough to economically justify the production of any legumes. However, fodder yield of pigeonpea in moderately poor environments indicated promise for the future when fodder will have economic values in the market or to the farmers.

Occasional prolonged rain due to typhoons was described as a serious threat for the successful establishment of dry season crops, particularly in the Philippines. The farmers' practice of growing mungbean by plowing the field followed by broadcasting the seeds and subsequent harrowing was found to give better crop growth, higher

grain yield and economic productivity compared to zero tillage planting of mungbean particularly under moisture stress situations. But mungbean or cowpea planted with zero tillage with little or no moisture stress exhibited excellent performance in other places (at IRRI). This indicated the need for further study on this issue. Further study is also suggested on production of legumes under zero tillage residual soil moisture conditions following lowland rice in acid soils.

APPENDIX

Table A-1. Regression equations and the coefficients of determination of the performances of different treatments shown in Figs. 6-7 through 6-9.

Figure No.	Treatment†	Regression equation‡	Coefficient of determination
6-7 (a)	CP	GR = -22.95 + 0.97 e ^s	0.99
	MB	GR = 14.34 + 0.54 e	0.83
	PP	GR = - 6.88 + 0.97 e	0.97
	PP + CP	GR = - 7.11 + 1.32 e	1.00
	PP + MB	GR = 22.59 + 1.21 e	1.00
6-7 (b)	CP	GR = -15.22 + 1.00 e	0.95
	MG	GR = - 5.02 + 0.53 e	0.78
	PP	GR = -25.46 + 0.97 e	0.97
	PP + CP	GR = 39.50 + 1.29 e	0.99
	PP + MB	GR = 6.20 + 1.21 e	0.99
6-8 (a)	CP	NR =-105.13 + 0.82 e	0.98
	MB	NR = -61.54 + 0.40 e	0.82
	PP	NR =-145.76 + 0.55 e	0.85
	PP + CP	NR =-198.75 + 0.94 e	0.98
	PP + MB	NR =-156.39 + 0.78 e	1.00
6-8 (b)	CP	NR =-229.01 + 0.92 e	0.89
	MB	NR =-198.29 + 0.48 e	0.65
	PP	NR =-246.31 + 0.61 e	0.79
	PP + CP	NR =-273.51 + 0.98 e	0.95
	PP + MB	NR =-283.15 + 0.85 e	0.89
6-9	CP	NR = -88.27 + 0.91 e	0.98
	MB	NR = -38.43 + 0.49 e	0.83
	PP	NR =-136.61 + 0.90 e	0.96
	PP + CP	NR =-167.62 + 1.25 e	0.99
	PP + MB	NR =-125.84 + 1.14 e	1.00

†CP = cowpea, MB = mungbean, and PP = pigeonpea.

‡GR = gross return, NR = net return.

^se = Environmental index.

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BIOGRAPHICAL SKETCH

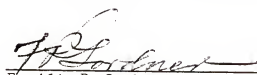
Nizam U. Ahmed was born on December 20, 1949, in Comilla, Bangladesh. He graduated from Tejgeron Poly Technic High School in 1964 and was admitted into the Bangladesh Agricultural University in 1965. In 1970 he earned the B. Sc. Ag. (Hons.) degree in agronomy. After graduation Nizam worked for an agricultural consulting firm and, as an in-service candidate, was admitted to the master's program. In 1974, Nizam received the M. Sc. Ag. degree in agronomy from the Bangladesh Agricultural University. In the same year, he joined the Agronomy Division of the Bangladesh Rice Research Institute (BRRI), as Scientific Officer. In 1976 he was awarded an IRRI-BRRI-IDRC scholarship for pursuing the M.S. program in agronomy (weed science) at the University of Philippines at Los Banos as a Research Fellow of the International Rice Research Institute (IRRI). After successful completion of the program Nizam returned to BRRI in early 1979 and joined the Rice Cropping Systems Division as Senior Scientific Officer. In early 1981, he was assigned the responsibility of the Acting Head of the said division. Nizam continued on that post until August 1983 when he was awarded another IRRI-BRRI-joint consortium of donors scholarship to pursue his Ph.D. degree in agronomy (farming systems) at the University of Florida. After completion of his course work, Nizam went to IRRI in the Philippines in 1985 to conduct his Ph.D. research and returned to the University of Florida campus recently. In 1985, he was promoted to Principal Scientific Officer.

Nizam married Nazma in 1976 and they have a son, Raju, who was born in the Philippines in 1978.

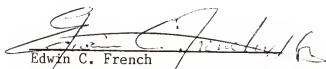
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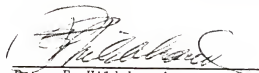
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December 1987



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